# COMPUTER PROGRAM LISTING APPENDIX

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Votc.h

```
/*
 ****************************************************************************
 * file:        tc_v2.h
 * date:        April 12, 2000
 * function:    tests turbo codes
 *              Modulation: QAM
 *              Decoder:    MAP algorithm
 ****************************************************************************
 */

#include <math.h>
#include <stdio.h>
#include <malloc.h>
#include <dos.h>


/* Definition of the first recursive systematic code (RSC1):                */
#define RSC1_ENC_MEM  4               /* encoder memory order               */
#define RSC1_STATES   (1 << RSC1_ENC_MEM)
#define RSC1_FP       035             /* forward polynomial in octal        */
#define RSC1_BP       023             /* backward polynomial in octal       */

/* Definition of the second recursive systematic code (RSC2):               */
#define RSC2_ENC_MEM  4               /* encoder memory order               */
#define RSC2_STATES   (1 << RSC2_ENC_MEM)
#define RSC2_FP       035             /* forward polynomial in octal        */
#define RSC2_BP       023             /* backward polynomial in octal       */

#define NR_ITER       8               /* nr. of iterative decoding stages   */
#define EBNO          6.0             /* Eb/No in dB                        */
#define MAX_ERRORS    1000            /* stop when this nr. is reached      */
#define INT_SIZE      6144            /* nr. of info bits to be ileaved     */

#define MAX           (exp(31.0))     /* limit soft outputs                 */
#define E_STEPS       1000            /* number of values for E_val         */
#define PRINT_BLOCKS  100             /* how often to print results         */
#define SEED1         13733           /* seeds for random nr. gen.          */
#define SEED2         1935791

#define SIGMA_12_4AM         sqrt(2.50 * pow(10.0,(-EBNO / 10.0))) /* A = 1.0 */
#define SIGMA_12_16QAM       sqrt(2.50 * pow(10.0,(-EBNO / 10.0)))
#define SIGMA_34_16QAM       sqrt((10.0/6.0) * pow(10.0,(-EBNO / 10.0)))

/* For 8AM, 64QAM, 256QAM, A = 0.5 => A*A = 0.25. Thus, Eav = 5.25*A*A = Eav/4 */
#define SIGMA_56_64QAM       sqrt(4.2/4 * pow(10.0,(-EBNO / 10.0)))
#define SIGMA_46_64QAM       sqrt(5.25/4 * pow(10.0,(-EBNO / 10.0)))
#define SIGMA_23_8AM         sqrt(5.25/4 * pow(10.0,(-EBNO / 10.0)))
#define SIGMA_12_8AM         sqrt(7.0/4 * pow(10.0,(-EBNO / 10.0)))
#define SIGMA_58_256QAM      sqrt(17.0/4 * pow(10.0,(-EBNO / 10.0)))
#define SIGMA_68_256QAM      sqrt((170.0/12)/4 * pow(10.0,(-EBNO / 10.0)))

/* For 4QAM (A = 0.5):*/
#define SIGMA_24_4QAM   sqrt(2.0/2.0/4 * pow(10.0,(-EBNO / 10.0))) /* 1 info */
#define SIGMA_26_4QAM   sqrt(2.0/(4.0/3)/4 * pow(10.0,(-EBNO / 10.0))) /* 2/3 info */
/* For 8QAM (A = 0.5):*/
#define SIGMA_4AM_of_46_8QAM   sqrt(6.0/4.0/4 * pow(10.0,(-EBNO / 10.0))) /* 2 info*/
#define SIGMA_2AM_of_46_8QAM   sqrt(6.0/4.0/4 * pow(10.0,(-EBNO / 10.0))) /* 2 info*/
#define SIGMA_4AM_of_26_8QAM   sqrt(6.0/2.0/4 * pow(10.0,(-EBNO / 10.0))) /* 1 info*/
#define SIGMA_2AM_of_26_8QAM   sqrt(6.0/2.0/4 * pow(10.0,(-EBNO / 10.0))) /* 1 info*/
#define SIGMA_4AM_of_13_8QAM   sqrt(6.0/2.0/4 * pow(10.0,(-EBNO / 10.0))) /* 1 info*/
#define SIGMA_2AM_of_13_8QAM   sqrt(6.0/2.0/4 * pow(10.0,(-EBNO / 10.0))) /* 1 info*/
#define SIGMA_36_64QAM   sqrt(42.0/6.0/4 * pow(10.0,(-EBNO / 10.0))) /* 3 info */

/* For 16QAM, 64QAM, 256QAM, 1024QAM (A = 0.5):*/
#define SIGMA_412_16QAM   sqrt(10.0/(8.0/3)/1 * pow(10.0,(-EBNO / 10.0))) /* 4/3 A=1 */
#define SIGMA_26_64QAM   sqrt(42.0/4.0/4 * pow(10.0,(-EBNO / 10.0))) /* 2 info */
#define SIGMA_824_256QAM   sqrt(170.0/(10.0/3)/4 * pow(10.0,(-EBNO / 10.0))) /* 10/3*/
#define SIGMA_1030_1024QAM   sqrt(341.0/(10.0/3)/4 * pow(10.0,(-EBNO / 10.0))) /*10/3 */
```

```
/* For 32QAM, 128QAM, 512QAM,(A = 0.5):*/
#define SIGMA_8AM_of_115_32QAM   sqrt(21.0/2/4 * pow(10.0,(-EBNO / 10.0))) /* 1 info */
#define SIGMA_4AM_of_115_32QAM   sqrt(5.00/(4/3)/4 * pow(10.0,(-EBNO / 10.0))) /*2/3*/
#define SIGMA_16AM_of_721_128QAM   sqrt(85.0/(8/3)/4 * pow(10.0,(-EBNO / 10.0))) /*4/3*/
#define SIGMA_8AM_of_721_128QAM    sqrt(21.0/2/4 * pow(10.0,(-EBNO / 10.0))) /* 1 info */
#define SIGMA_32AM_of_39_512QAM   sqrt(341.0/4/4*pow(10.0,(-EBNO / 10.0))) /* 2 info */
#define SIGMA_16AM_of_39_512QAM   sqrt(85.00/2/4*pow(10.0,(-EBNO / 10.0))) /* 1 info */

/* For 32QAM (A = 0.5):*/
#define SIGMA_8AM_of_32QAM   sqrt(26.0/6/4 * pow(10.0,(-EBNO / 10.0))) /* 3 info */
#define SIGMA_4AM_of_32QAM   sqrt(26.0/6/4 * pow(10.0,(-EBNO / 10.0))) /* 3 info */

/* For R57_128QAM (A = 0.5):*/
#define SIGMA_16AM_of_128QAM   sqrt(106.0/10/4 * pow(10.0,(-EBNO / 10.0))) /* 3 info */
#define SIGMA_8AM_of_128QAM    sqrt(106.0/10/4 * pow(10.0,(-EBNO / 10.0))) /* 2 info */

/* For R69_512QAM (A = 0.5):*/
#define SIGMA_32AM_of_512QAM   sqrt(426.0/12/4*pow(10.0,(-EBNO / 10.0))) /* 4 info */
#define SIGMA_16AM_of_512QAM   sqrt(426.0/12/4*pow(10.0,(-EBNO / 10.0))) /* 2 info */

/* For R710_1024QAM (A = 0.5):*/
#define SIGMA_710_1024QAM   sqrt((341.0/7)/4 * pow(10.0,(-EBNO / 10.0))) /* 3.5 info */

/* Define the particular coding and modulation case for simulation   */
#define R36_64QAM

#define BIT_HIST
#define THRESHOLD_ITER       10       /* record bit histogram for higher iterations */
#define MAX_BIT_HIST_ARRAY   (2 * INT_SIZE)
#define ERROR_FILE_NAME      "../results/R36_64QAM_6144_test_30.err"
#define FRAME_HIST_FILE_NAME "../results/test.fhist"
#define BIT_HIST_FILE_NAME   "../results/map.hist"
#define INTERLEAVER_FILE     "../results/6144/s6144"


 /*
 * Note1:
Make sure that for each simulation, the INT_SIZE represents the size of the interleaver
defined in INTERLEAVER_FILE
 */

/*
 * Note2:
 *
In rate 4/6 64QAM_TTCM only two bits out of four are coded rate half. Therefore,
the first half of the interleaver table used has a INT_SIZE/2 interleaver,
the rest is mapping the bits in the same position.
 */
```

## Votc.c

```
/*
 ***************************************************************************
 * file:        tc_v2.c
 * date:        March 20, 2000
 * function:    tests turbo codes
 *              Modulation: QAM
 *              Decoder:    MAP algorithm
 ***************************************************************************
 */

#include "tc_v2.h"

typedef struct {
  int         enc_state;              /* encoder state                        */
  int         nr_states;              /* number of encoder states             */
  int         enc_mem;                /* encoder memory                       */
  int         bp;                     /* backward polynomial                  */
  int         fp;                     /* forward polynomial                   */
  int         *P0state;               /* previous state for i=0 branch        */
  int         *P1state;               /* previous state for i=1 branch        */
  int         *N0state;               /* next state for i=0 branch            */
  int         *N1state;               /* next state for i=1 branch            */
  int         *Coded0;                /* coded bit for i=0 branch             */
  int         *Coded1;                /* coded bit for i=1 branch             */
} jat_code;

void          jat_map1(jat_code *, double *, double *, double *, double *);
void          jat_map2(jat_code *, double *, double *, double *, double *);
void          jat_trellis_bp_fp(jat_code *);
int           jat_ps(jat_code *, int);
int           jat_enc_bp_fp(jat_code *, int);
void          r_ileav(double *, int *);
void          r_ileava(int *, int *);
void          r_deileav(double *, int *);
void          r_deileava(int *, int *);
double        nrgen();
int           nrgenbin();
double        gasdev();
int           errors(int *, double *, int, int);
int           print_err(int *, double *, int, int, int *);
double        find_tx_I(int);
double        find_tx_Q(int);


int           *frame_hist;            /* how many frames with how many errors*/
int           **bit_hist_array;       /* pointer to NR_ITER pointers
                                         to blocks of data organised as:
                                               block nr.,bit pos. in error,
                                                block nr.,bit pos. in error   */
int           *bit_hist_block;        /* current number of blocks in error
                                         for each iteration                  */
int           frame_err;              /* frame/block error rate               */
int           total_err;              /* total nr. of err. after NR_ITER      */
long          s1, s2;                 /* seed generators                      */


/*************************************************************************/
main()
{
jat_code      *jat_code1;
jat_code      *jat_code2;
int           u1, u2, u3, u4, u5, u6;    /* bits of a 64QAM symbol in TTCM   */
double        tx_I, tx_Q, rx_I, rx_Q;
double        v00_I, v00_Q, v01_I, v01_Q, v10_I, v10_Q, v11_I, v11_Q;
int           i, j, k, block, iteration;
int           *rule    ;         /* interleaver                              */
int           *data;             /* the information block of data            */
```

```
int           *data_i;          /* the interleaved information block of data*/
int           *data_d;          /* the deinterleaved inf. block of data     */
int           *Enc1;            /* Encoder1 output                          */
int           *Enc2;            /* Encoder2 output                          */
int           *no_err;          /* stores nr. err. for each iteration       */
double        *D1_data;         /* Decoder1 input data                      */
double        *D1_parity;       /* Decoder1 input parity                    */
double        *D1_app;          /* Decoder1 input a priori information      */
double        *D1_exi;          /* Decoder1 output extrinsic information    */
double        *D2_data;         /* Decoder2 input data                      */
double        *D2_parity;       /* Decoder2 input parity                    */
double        *D2_app;          /* Decoder2 input a priori information      */
double        *D2_exi;          /* Decoder2 output extrinsic information    */
double        *Dec_data;        /* Decoded data                             */
double        *Zero_data;       /* zero data                                */
double        d0, d1, d2, d3, d4, L_d0, L_d1, L_d2, L_d3, tx, rx,K,noise1,n;
double        L_d4, L_d5;
double        L_u1, L_u2, L_u3, L_u4, L_u5, L_u6;
double        noise_I, noise_Q;
FILE          *out_file = NULL;

s1        = SEED1;  /* initialize the seeds for the noise generator         */
s2        = SEED2;
frame_err = 0;
total_err = 0;

/*
 * initialize the code structures:
 */
jat_code1            = (jat_code *)malloc(sizeof(jat_code));
jat_code1->enc_mem   = RSC1_ENC_MEM;
jat_code1->bp        = RSC1_BP;
jat_code1->fp        = RSC1_FP;
jat_code1->enc_state = 0;
jat_code1->nr_states = (1 << RSC1_ENC_MEM);
jat_code1->P0state   = (int *)malloc(sizeof(int)*jat_code1->nr_states);
jat_code1->P1state   = (int *)malloc(sizeof(int)*jat_code1->nr_states);
jat_code1->N0state   = (int *)malloc(sizeof(int)*jat_code1->nr_states);
jat_code1->N1state   = (int *)malloc(sizeof(int)*jat_code1->nr_states);
jat_code1->Coded0    = (int *)malloc(sizeof(int)*jat_code1->nr_states);
jat_code1->Coded1    = (int *)malloc(sizeof(int)*jat_code1->nr_states);
jat_trellis_bp_fp(jat_code1);
jat_code2            = (jat_code *)malloc(sizeof(jat_code));
jat_code2->enc_mem   = RSC2_ENC_MEM;
jat_code2->bp        = RSC2_BP;
jat_code2->fp        = RSC2_FP;
jat_code2->enc_state = 0;
jat_code2->nr_states = (1 << RSC2_ENC_MEM);
jat_code2->P0state   = (int *)malloc(sizeof(int)*jat_code2->nr_states);
jat_code2->P1state   = (int *)malloc(sizeof(int)*jat_code2->nr_states);
jat_code2->N0state   = (int *)malloc(sizeof(int)*jat_code2->nr_states);
jat_code2->N1state   = (int *)malloc(sizeof(int)*jat_code2->nr_states);
jat_code2->Coded0    = (int *)malloc(sizeof(int)*jat_code2->nr_states);
jat_code2->Coded1    = (int *)malloc(sizeof(int)*jat_code2->nr_states);
jat_trellis_bp_fp(jat_code2);


data = (int *)malloc(sizeof(int) * INT_SIZE);
if(data == 0)
  {
    printf("Couldn't allocate data memory!\n");
    exit(1);
  }

data_i = (int *)malloc(sizeof(int) * INT_SIZE);
if(data_i == 0)
  {
    printf("Couldn't allocate data_i memory!\n");
    exit(1);
  }
```

```
data_d = (int *)malloc(sizeof(int) * INT_SIZE);
if(data_d == 0)
  {
    printf("Couldn't allocate data_d memory!\n");
    exit(1);
  }

no_err = (int *)malloc(sizeof(int) * NR_ITER);
if(no_err == 0)
  {
    printf("Couldn't allocate no_err memory!\n");
    exit(1);
  }
else
  for(i = 0; i < NR_ITER; i++)
    no_err[i] = 0;

Enc1 = (int *)malloc(sizeof(int) * INT_SIZE);
if(Enc1 == 0)
  {
    printf("Couldn't allocate Enc1 memory!\n");
    exit(1);
  }

Enc2 = (int *)malloc(sizeof(int) * INT_SIZE);
if(Enc2 == 0)
  {
    printf("Couldn't allocate Enc2 memory!\n");
    exit(1);
  }

D1_data = (double *)malloc(sizeof(double) * INT_SIZE);
if(D1_data == 0)
  {
    printf("Couldn't allocate D1_data memory!\n");
    exit(1);
  }

D1_parity = (double *)malloc(sizeof(double) * INT_SIZE);
if(D1_parity == 0)
  {
    printf("Couldn't allocate D1_parity memory!\n");
    exit(1);
  }

D1_app = (double *)malloc(sizeof(double) * INT_SIZE);
if(D1_app == 0)
  {
    printf("Couldn't allocate D1_app memory!\n");
    exit(1);
  }

D1_exi = (double *)malloc(sizeof(double) * INT_SIZE);
if(D1_exi == 0)
  {
    printf("Couldn't allocate D1_exi memory!\n");
    exit(1);
  }

D2_data = (double *)malloc(sizeof(double) * INT_SIZE);
if(D2_data == 0)
  {
    printf("Couldn't allocate D2_data memory!\n");
    exit(1);
  }

D2_parity = (double *)malloc(sizeof(double) * INT_SIZE);
if(D2_parity == 0)
  {
    printf("Couldn't allocate D2_parity memory!\n");
    exit(1);
```

```
  }

D2_app = (double *)malloc(sizeof(double) * INT_SIZE);
if(D2_app == 0)
  {
    printf("Couldn't allocate D2_app memory!\n");
    exit(1);
  }

D2_exi = (double *)malloc(sizeof(double) * INT_SIZE);
if(D2_exi == 0)
  {
    printf("Couldn't allocate D2_exi memory!\n");
    exit(1);
  }

Dec_data = (double *)malloc(sizeof(double) * INT_SIZE);
if(Dec_data == 0)
  {
    printf("Couldn't allocate Dec_data memory!\n");
    exit(1);
  }

Zero_data = (double *)malloc(sizeof(double) * INT_SIZE);
if(Zero_data == 0)
  {
    printf("Couldn't allocate Zero_data memory!\n");
    exit(1);
  }
for(i = 0; i < INT_SIZE; i++)
  Zero_data[i] = 0.0;

frame_hist = (int *)malloc(sizeof(int) * (INT_SIZE+1) * NR_ITER);
if(frame_hist == 0)
  {
    printf("Couldn't allocate frame_hist memory!\n");
    exit(1);
  }
else
  {
    for(i = 0; i < (INT_SIZE+1)*NR_ITER; i++)
      frame_hist[i] = 0;
  }

bit_hist_array = (int **)malloc(sizeof(int *) * 2 * NR_ITER);
if(bit_hist_array == 0)
  {
    printf("Couldn't allocate bit_hist_array memory!\n");
    exit(1);
  }
else
  {
    for(i = THRESHOLD_ITER; i <= NR_ITER; i++)
      {
        bit_hist_array[i] = (int *)malloc(sizeof(int) * MAX_BIT_HIST_ARRAY);
        bit_hist_array[i+NR_ITER] = bit_hist_array[i]; /* store the original pointer */
        if(bit_hist_array[i] == 0)
          {
            printf("Couldn't allocate bit_hist_array[i] memory!\n");
            exit(1);
          }
      }
  }

bit_hist_block = (int *)malloc(sizeof(int) * (NR_ITER+1));
if(bit_hist_block == 0)
  {
    printf("Couldn't allocate bit_hist_block memory!\n");
    exit(1);
  }
else
```

```
  {
    for(i = 0; i <= NR_ITER; i++)
      bit_hist_block[i] = 1;
  }

rule = (int *)malloc(sizeof(int) * INT_SIZE * 2);
if(rule == 0)
  {
    printf("Couldn't allocate rule memory!\n");
    exit(1);
  }

for(i = 0; i < INT_SIZE; i++)
  rule[2*i] = 0;

/*
 * read the interleaver file
 */

out_file = fopen(INTERLEAVER_FILE, "r");

if(!out_file)
  {
    printf("Error1: the output file could not be opened!\n");
    exit (1);
  }
for(i = 0; i < INT_SIZE; i++)
  fscanf(out_file, "%d%d", &i, &rule[2*i+1]);
fclose(out_file);


/*
 * initialize the noise generator seeds in order to have the same data and
 * noise for different random interleavers
 */
s1 = SEED1;
s2 = SEED2;

/*
 * start the big loop:
 */
for(block = 1; total_err < MAX_ERRORS; block++)
  {
    jat_code1->enc_state = 0;                    /* reset encoder1's state    */
    jat_code2->enc_state = 0;                    /* reset encoder2's state    */
    for(i = 0; i < INT_SIZE; i++)                /* no app for first decoder  */
      D1_app[i] = 1.0;

    /*
     * generate random data:
     */
    for(i = 0; i < INT_SIZE; i++)
      data[i] = nrgenbin();

    /*
     * encoder1:
     */
    for(i = 0; i < INT_SIZE; i++)
      Enc1[i] = jat_enc_bp_fp(jat_code1, data[i]);

    /*
     * interleave data:
     */
    for(i = 0; i < INT_SIZE; i++)
      data_i[i] = data[i];
    r_ileava(data_i, rule);

    /*
     * encoder2:
     */
    for(i = 0; i < INT_SIZE; i++)
```

```
      Enc2[i] = jat_enc_bp_fp(jat_code2, data_i[i]);

    /*
     * deinterleave data:
     */
    for(i = 0; i < INT_SIZE; i++)
      data_d[i] = data[i];
    r_deileava(data_d, rule);

    /*
     * modulate and add AWGN noise:
     */


#ifdef R12_4AM
        /*
         * Channel:
         * d0 is MSB and d1 is LSB in a 4-AM:(d0,d1) = 01--00-|-10--11
         *                                              -3  -1    1   3
         */

    n   = (-1.0) / (2 * SIGMA_12_4AM * SIGMA_12_4AM);
    for(i = 0; i < INT_SIZE; i++)
      {
        d0 = data[i];
        if(i & 0x1)
          d1 = Enc1[i];
        else
          d1 = Enc2[i];
        tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0;
        rx   = tx + SIGMA_12_4AM * gasdev();
        L_d0 = log((exp(n*(rx-1)*(rx-1))+exp(n*(rx-3)*(rx-3))) /
                   (exp(n*(rx+1)*(rx+1))+exp(n*(rx+3)*(rx+3))));
        L_d1 = log((exp(n*(rx+3)*(rx+3))+exp(n*(rx-3)*(rx-3))) /
                   (exp(n*(rx-1)*(rx-1))+exp(n*(rx+1)*(rx+1))));
        D1_data[i] = L_d0;
        if(i & 0x1)
          {
            D1_parity[i] = L_d1;
            D2_parity[i] = 0.0;
          }
        else
          {
            D1_parity[i] = 0.0;
            D2_parity[i] = L_d1;
          }
      }
#endif


#ifdef R13_8AM
    /*
     * Channel:
     * d0 is MSB and d2 is LSB in 8-AM:(d0,d1,d2):
     *       010---011---001---000---100---101---111---110
     *      -3.5  -2.5  -1.5  -0.5   0.5   1.5   2.5   3.5
     */

    n   = (-1.0) / (2 * SIGMA_13_8AM * SIGMA_13_8AM);
    for(i = 0; i < INT_SIZE; i++)
      {
        d0 = data[i];
        if(i & 0x1)
          {
            d1 = Enc1[i];
            d2 = Enc2[i];
          }
        else
          {
            d1 = Enc2[i];
            d2 = Enc1[i];
```

```
        }

      tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0 + (((2*d0-1)*(2*d1-1))<0?(d2-0.5):(0.5-d2));
      rx   = tx + SIGMA_13_8AM * gasdev();
      L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                 exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                 exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));

      L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                 exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                 exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

      L_d2 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                 exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
                (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                 exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));

      D1_data[i] = L_d0;
      if(i & 0x1)
        {
          D1_parity[i] = L_d1;
          D2_parity[i] = L_d2;
        }
      else
        {
          D1_parity[i] = L_d2;
          D2_parity[i] = L_d1;
        }
    }
#endif

#ifdef R12_8AM
    /*
     * Channel:
     * d0 is MSB and d2 is LSB in 8-AM:(d0,d1,d2):
     *       010---011---001---000---100---101---111---110
     *      -3.5  -2.5  -1.5  -0.5   0.5   1.5   2.5   3.5
     */
    /*
     * Channel:  we transmit two 8AM symbols to emulate a 64QAM symbol.
     * 6 info bits and 6 parity bits are mapped to 2 64QAM symbols which in
     * turn are simulated as 4 8AM symbols to achieve 3bit/s/Hz
     *
     * INT_SIZE to be a multiple of 6
     */

    n   = (-1.0) / (2 * SIGMA_12_8AM * SIGMA_12_8AM);
    for(i = 0; i < INT_SIZE; i++)
      {
        /* symbol 1 */
        d0  = data[i];
        d1  = data[i+1];
        d2  = Enc1[i];
        tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0 + (((2*d0-1)*(2*d1-1))<0?(d2-0.5):(0.5-d2));
        rx   = tx + SIGMA_12_8AM * gasdev();
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                   exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                  (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                   exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));

        L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                   exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                  (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                   exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

        L_d2 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                   exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
                  (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                   exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));
```

```
D1_data[i]     = L_d0;
D1_data[i+1]   = L_d1;
D1_parity[i]   = L_d2;
D1_parity[i+1] = 0;
D2_parity[i]   = 0;

/* symbol 2 */
d0   = data[i+2];
d1   = Enc1[i+2];
d2   = Enc2[i+1];
tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0 + (((2*d0-1)*(2*d1-1))<0?(d2-0.5):(0.5-d2));
rx   = tx + SIGMA_12_8AM * gasdev();
L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
           exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
          (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
           exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));

L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
           exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
          (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
           exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

L_d2 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
           exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
          (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
           exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));
D1_data[i+2]   = L_d0;
D1_parity[i+2] = L_d1;
D2_parity[i+1] = L_d2;
D2_parity[i+2] = 0;

/* symbol 3 */
d0   = data[i+3];
d1   = data[i+4];
d2   = Enc2[i+3];
tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0 + (((2*d0-1)*(2*d1-1))<0?(d2-0.5):(0.5-d2));
rx   = tx + SIGMA_12_8AM * gasdev();
L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
           exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
          (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
           exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));

L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
           exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
          (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
           exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

L_d2 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
           exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
          (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
           exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));
D1_data[i+3]   = L_d0;
D1_data[i+4]   = L_d1;
D2_parity[i+3] = L_d2;
D1_parity[i+3] = 0;
D2_parity[i+4] = 0;

/* symbol 4 */
d0   = data[i+5];
d1   = Enc1[i+4];
d2   = Enc2[i+5];
tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0 + (((2*d0-1)*(2*d1-1))<0?(d2-0.5):(0.5-d2));
rx   = tx + SIGMA_12_8AM * gasdev();
L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
           exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
          (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
           exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));

L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
           exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
          (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
```

```
                    exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

        L_d2 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                    exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
                   (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                    exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));
        D1_data[i+5]   = L_d0;
        D1_parity[i+4] = L_d1;
        D2_parity[i+5] = L_d2;
        D1_parity[i+5] = 0;

        i = i+5;
      }
#endif

#ifdef R23_8AM
    /*
     * Channel:
     * d0 is MSB and d2 is LSB in 8-AM:(d0,d1,d2):
     *       010---011---001---000---100---101---111---110
     *      -3.5  -2.5  -1.5  -0.5   0.5   1.5   2.5   3.5
     */

    n   = (-1.0) / (2 * SIGMA_23_8AM * SIGMA_23_8AM);
    for(i = 0; i < INT_SIZE; i++)
      {
        d0 = data[i];
        d1 = data[i+1];
        if(i & 0x4)
          d2 = Enc1[i];
        else
          d2 = Enc2[i];


        tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0 + (((2*d0-1)*(2*d1-1))<0?(d2-0.5):(0.5-d2));
        rx   = tx + SIGMA_23_8AM * gasdev();
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                    exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                   (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                    exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));

        L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                    exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                   (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                    exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

        L_d2 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                    exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
                   (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                    exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));

        D1_data[i]   = L_d0;
        D1_data[i+1] = L_d1;
        if(i & 0x4)
          {
            D1_parity[i]   = L_d2;
            D1_parity[i+1] = 0;
            D2_parity[i]   = 0;
            D2_parity[i+1] = 0;
          }
        else
          {
            D1_parity[i]   = 0;
            D1_parity[i+1] = 0;
            D2_parity[i]   = L_d2;
            D2_parity[i+1] = 0;
          }

        i++;
      }
#endif
```

```
#ifdef R35_32QAM
    /*
     * I dimension:
     * d0 is MSB and d2 is LSB in 8-AM:(d0,d1,d2):
     *       010---011---001---000---100---101---111---110
     *      -3.5  -2.5  -1.5  -0.5   0.5   1.5   2.5   3.5
     * Q dimension:
     * d0 is MSB and d1 is LSB in a 4-AM:(d0,d1):
     *       01----00----10----11
     *     -1.5  -0.5   0.5   1.5
     *
     *
     * We transmit one 8AM symbol and one 4AM symbol to emulate a 32QAM symbol.
     * 6 info bits and 4 parity bits are mapped to 2 32QAM symbols.
     *
     * INT_SIZE to be a multiple of 6
     */

    for(i = 0; i < INT_SIZE; i++)
      {
        /* symbol 1: 8AM */
    d0  = data[i];
    d1  = data[i+2];
        d2  = Enc1[i];
        tx  = 2*d0 - 2*d1 + 4*d0*d1 - 1.0 + (((2*d0-1)*(2*d1-1))<0?(d2-0.5):(0.5-d2));
    rx  = tx + SIGMA_8AM_of_32QAM * gasdev();
        n   = (-1.0) / (2 * SIGMA_8AM_of_32QAM * SIGMA_8AM_of_32QAM);
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                    exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                   (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                    exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));

        L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                    exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                   (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                    exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

        L_d2 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                    exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
                   (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                    exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));
        D1_data[i]     = L_d0;
        D1_data[i+2]   = L_d1;
        D1_parity[i]   = L_d2;
        D1_parity[i+1] = 0.0;
        D1_parity[i+2] = 0.0;
        D2_parity[i]   = 0.0;
        D2_parity[i+2] = 0.0;

        /* symbol 2: 4AM */
        d0 = data[i+1];
        d1 = Enc2[i+1];
        tx   = d0 - d1 + 2*d0*d1 - 0.5;
        rx   = tx + SIGMA_4AM_of_32QAM * gasdev();
        n   = (-1.0) / (2 * SIGMA_4AM_of_32QAM * SIGMA_4AM_of_32QAM);
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))) /
                   (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5))));
        L_d1 = log((exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx-1.5)*(rx-1.5))) /
                   (exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx+0.5)*(rx+0.5))));
        D1_data[i+1]   = L_d0;
        D2_parity[i+1] = L_d1;

        /* symbol 3: 8AM */
    d0   = data[i+3];
    d1   = data[i+5];
        d2   = Enc2[i+4];
        tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0 + (((2*d0-1)*(2*d1-1))<0?(d2-0.5):(0.5-d2));
    rx  = tx + SIGMA_8AM_of_32QAM * gasdev();
        n   = (-1.0) / (2 * SIGMA_8AM_of_32QAM * SIGMA_8AM_of_32QAM);
```

```
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                   exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                  (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                   exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));

        L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                   exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                  (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                   exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

        L_d2 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                   exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
                  (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                   exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));
        D1_data[i+3]   = L_d0;
        D1_data[i+5]   = L_d1;
        D1_parity[i+4] = 0.0;
        D1_parity[i+5] = 0.0;
        D2_parity[i+3] = 0.0;
        D2_parity[i+4] = L_d2;
        D2_parity[i+5] = 0.0;

        /* symbol 4: 4AM */
        d0 = data[i+4];
        d1 = Enc1[i+3];
        tx   = d0 - d1 + 2*d0*d1 - 0.5;
        rx   = tx + SIGMA_4AM_of_32QAM * gasdev();
        n    = (-1.0) / (2 * SIGMA_4AM_of_32QAM * SIGMA_4AM_of_32QAM);
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))) /
                  (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5))));
        L_d1 = log((exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx-1.5)*(rx-1.5))) /
                  (exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx+0.5)*(rx+0.5))));
        D1_data[i+4]   = L_d0;
        D1_parity[i+3] = L_d1;

        i = i+5;
      }
#endif


#ifdef R46_64QAM_TTCM_VoCAL
    /* Option 4
     * Channel: I & Q defined as
     *       -|-----|-----|-----|-----|-----|-----|-----|-
     *      -3.5  -2.5  -1.5  -0.5   0.5   1.5   2.5   3.5
     * the 64QAM symbol is defined as: (u1, u2, u3, u4, u5, u6)
     * where u4 = d0
     *       u3 = d1
     *       u2 = p0 parity from ENC_H
     *       u1 = q1 parity from ENC_V
     *       u5 = d uncoded
     *       u6 = d uncoded
     * Use s4096v interleaver - only first 2048 bits are interleaved
     */

    n   = (-1.0) / (2 * SIGMA_46_64QAM * SIGMA_46_64QAM);
    for(i = 0; i < INT_SIZE/2 -1;)
      {
       /* Encode only first half of INT_SIZE
        * d0, d1, d2, d3,...    up to INT_SIZE/2 - 1
        * p0,  0, p2,  0,...
        *  0, q1,  0, q3,...
        */
       u4 = data[i];
       u3 = data[i+1];
       u2 = Enc1[i];
       u1 = Enc2[i+1];
       u5 = data[i+INT_SIZE/2];
       u6 = data[i+INT_SIZE/2+1];

       k = u6+2*u5+4*u4+8*u3+16*u2+32*u1;
```

# COMPUTER PROGRAM LISTING APPENDIX

```
tx_I = find_tx_I(k);
tx_Q = find_tx_Q(k);
rx_I = tx_I + SIGMA_46_64QAM * gasdev();
rx_Q = tx_Q + SIGMA_46_64QAM * gasdev();

L_d0 = log((exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
           exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
           exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
           exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
           exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
           exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
           exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
           exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
           exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
           exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
           exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
           exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
           exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
           exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
           exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
           exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
           exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
           exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
           exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
           exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
           exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
           exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
           exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
           exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
           exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
           exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
           exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
           exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
           exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
           exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
           exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
           exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+3.5)*(rx_Q+3.5)))) /
          (exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
           exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
           exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
           exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
           exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
           exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
           exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
           exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
           exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
           exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
           exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
           exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
           exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
           exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
           exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
           exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
           exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
           exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
           exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
           exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
           exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
           exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
           exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
           exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
           exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
           exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
           exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
           exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
           exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
           exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
           exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
           exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+3.5)*(rx_Q+3.5)))));
```

# COMPUTER PROGRAM LISTING APPENDIX

```
L_d1 = log((exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
           exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
           exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
           exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
           exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
           exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
           exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
           exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
           exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
           exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
           exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
           exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
           exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
           exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
           exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
           exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
           exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
           exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
           exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
           exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
           exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
           exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
           exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
           exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
           exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
           exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
           exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
           exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
           exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
           exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
           exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
           exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+2.5)*(rx_Q+2.5)))) /
          (exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
           exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
           exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
           exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
           exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
           exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
           exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
           exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
           exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
           exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
           exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
           exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
           exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
           exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
           exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
           exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
           exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
           exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
           exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
           exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
           exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
           exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
           exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
           exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
           exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
           exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
           exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
           exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
           exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
           exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
           exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
           exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+3.5)*(rx_Q+3.5))));

 L_d2 = log((exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
            exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
            exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
            exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
            exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
            exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
```

```
                    exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                    exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                    exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                    exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                    exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                    exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                    exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                    exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                    exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                    exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                    exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                    exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                    exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                    exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                    exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                    exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                    exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                    exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                    exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                    exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                    exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                    exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                    exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                    exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                    exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                    exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+3.5)*(rx_Q+3.5)))) /
                   (exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                    exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                    exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                    exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                    exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                    exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                    exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                    exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                    exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                    exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                    exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                    exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                    exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                    exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                    exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                    exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                    exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                    exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                    exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                    exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                    exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                    exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                    exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                    exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                    exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                    exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                    exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                    exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                    exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                    exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                    exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                    exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+3.5)*(rx_Q+3.5))));

L_d3 = log((exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
            exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
            exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
            exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
            exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
            exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
            exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
            exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
            exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
            exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
            exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
            exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
```

```
                    exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                    exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                    exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                    exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                    exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                    exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                    exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                    exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                    exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                    exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                    exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                    exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                    exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                    exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                    exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                    exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                    exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                    exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                    exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                    exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+3.5)*(rx_Q+3.5)))) /
                   (exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                    exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                    exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                    exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                    exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                    exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                    exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                    exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                    exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                    exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                    exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                    exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                    exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                    exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                    exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                    exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                    exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                    exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                    exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                    exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                    exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                    exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                    exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                    exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                    exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                    exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                    exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                    exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                    exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                    exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                    exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                    exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+0.5)*(rx_Q+0.5)))));

            D1_data[i]     = L_d3;
            D1_data[i+1]   = L_d2;
            D1_data[i + INT_SIZE/2]     = rx_I;
            D1_data[i + INT_SIZE/2 + 1] = rx_Q;
            D1_parity[i]   = L_d1;
            D1_parity[i+1] = 0;
            D2_parity[i]   = 0;
            D2_parity[i+1] = L_d0;

            i = i + 2;
          }
#endif


#ifdef R46_64QAM_TTCM_Ungerboeck_Map
    /* Option3: conventional set partitioning used in TCM
     * Channel: I & Q defined
     *       -|-----|-----|-----|-----|-----|-----|-----|-
```

```
*      -3.5  -2.5  -1.5  -0.5   0.5   1.5   2.5   3.5
* the 64QAM symbol is defined as: (u1, u2, u3, u4, u5, u6)
* where
*       u6 = d0
*       u5 = d1
*       u4 = d2
*       u3 = d3
*       u2 = p0 parity from ENC_H
*       u1 = q1 parity from ENC_V
*/
/*
 * deinterleave data:
 */
for(i = 0; i < INT_SIZE; i++)
  data_d[i] = data[i];
r_deileava(data_d, rule);
n   = (-1.0) / (2 * SIGMA_46_64QAM * SIGMA_46_64QAM);
for(i = 0; i < INT_SIZE;)
  {
    /* Puncturing patern is:
     * d0, d1, d2, d3,...
     * p0,  0,  0,  0,...
     *  0,  0, q2,  0,...
     */

    u1 = Enc1[i];
    u2 = Enc2[i];
    u6 = data_d[i+3];
    u5 = data_d[i+2];
    u4 = data_d[i+1];
    u3 = data_d[i];

    k = u6+2*u5+4*u4+8*u3+16*u2+32*u1;

    tx_I = find_tx_I(k);
    tx_Q = find_tx_Q(k);

    rx_I = tx_I + SIGMA_46_64QAM * gasdev();
    rx_Q = tx_Q + SIGMA_46_64QAM * gasdev();

    L_d0 = log((exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
```

```
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+3.5)*(rx_Q+3.5)))) /
               (exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+3.5)*(rx_Q+3.5))));

L_d1 = log((exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+2.5)*(rx_Q+2.5)))) /
               (exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
```

```
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+3.5)*(rx_Q+3.5)))));

L_d2 = log((exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+3.5)*(rx_Q+3.5)))) /
               (exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
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```
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+3.5)*(rx_Q+3.5))));

L_d3 = log((exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+3.5)*(rx_Q+3.5)))) /
               (exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
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                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+0.5)*(rx_Q+0.5)))));

L_d4 = log((exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+2.5)*(rx_Q+2.5)))) /
               (exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
```

```
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-3.5)*(rx_Q-3.5))));

L_d5 = log((exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I+3.5)*(rx_I+3.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I+2.5)*(rx_I+2.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I+1.5)*(rx_I+1.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I+0.5)*(rx_I+0.5) + (rx_Q-3.5)*(rx_Q-3.5)))) /
               (exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-3.5)*(rx_Q-3.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-2.5)*(rx_Q-2.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-1.5)*(rx_Q-1.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q-0.5)*(rx_Q-0.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+0.5)*(rx_Q+0.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+1.5)*(rx_Q+1.5))) +
                exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+2.5)*(rx_Q+2.5))) +
                exp(n*((rx_I-0.5)*(rx_I-0.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
```

```
                    exp(n*((rx_I-1.5)*(rx_I-1.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                    exp(n*((rx_I-2.5)*(rx_I-2.5) + (rx_Q+3.5)*(rx_Q+3.5))) +
                    exp(n*((rx_I-3.5)*(rx_I-3.5) + (rx_Q+3.5)*(rx_Q+3.5)))));
          D1_data[i]     = L_d2;
          D1_data[i+1]   = L_d3;
          D1_data[i+2]   = L_d4;
          D1_data[i+3]   = L_d5;
          D1_parity[i]   = L_d0;
          D1_parity[i+1] = 0.0;
          D1_parity[i+2] = 0.0;
          D1_parity[i+3] = 0.0;
          D2_parity[i]   = L_d1;
          D2_parity[i+1] = 0.0;
          D2_parity[i+2] = 0.0;
          D2_parity[i+3] = 0.0;

          i = i + 4;
        }
      /*
       * interleave data:
       */
      r_ileav(D1_data, rule);

#endif


#ifdef R46_64QAM_IQ_Natural_Map
      /* Option2
       * Channel: I = (u1, u2, u3), Q = (u4, u5, u6) defined using natural mapping:
       *       000   001   010   011   100   101   110   111
       *       -|-----|-----|-----|-----|-----|-----|-----|-
       *      -3.5  -2.5  -1.5  -0.5   0.5   1.5   2.5   3.5
       * the 64QAM symbol is defined as: (u1, u2, u3, u4, u5, u6)
       * where:
       *       u1 = d0
       *       u2 = d1
       *       u3 = p0 parity from ENC_V
       *       u4 = d2
       *       u5 = d3
       *       u6 = q0 parity from ENC_H
       *
       */

      /*
       * deinterleave data:
       */
      for(i = 0; i < INT_SIZE; i++)
        data_d[i] = data[i];
      r_deileava(data_d, rule);

      n   = (-1.0) / (2 * SIGMA_46_64QAM * SIGMA_46_64QAM);

      for(i = 0; i < INT_SIZE;)
        {
          /* Puncturing patern is:
           * d0, d1, d2, d3,...
           * p0,  0,  0,  0,...
           * q0,  0,  0,  0,...
           */

          u1 = data_d[i];
          u2 = data_d[i+1];
           u3 = Enc1[i];
          u4 = data_d[i+2];
          u5 = data_d[i+3];
          u6 = Enc2[i];

          tx_I = -3.5 + u3 + 2*u2 +4*u1;
          tx_Q = -3.5 + u6 + 2*u5 +4*u4;

          rx_I = tx_I + SIGMA_46_64QAM * gasdev();
```

```
    rx_Q = tx_Q + SIGMA_46_64QAM * gasdev();

    L_u1 = log((exp(n*((rx_I-3.5)*(rx_I-3.5)))+
               exp(n*((rx_I-2.5)*(rx_I-2.5)))+
               exp(n*((rx_I-1.5)*(rx_I-1.5)))+
               exp(n*((rx_I-0.5)*(rx_I-0.5))))/
              (exp(n*((rx_I+3.5)*(rx_I+3.5)))+
               exp(n*((rx_I+2.5)*(rx_I+2.5)))+
               exp(n*((rx_I+1.5)*(rx_I+1.5)))+
               exp(n*((rx_I+0.5)*(rx_I+0.5)))));
    L_u2 = log((exp(n*((rx_I-3.5)*(rx_I-3.5)))+
               exp(n*((rx_I-2.5)*(rx_I-2.5)))+
               exp(n*((rx_I+1.5)*(rx_I+1.5)))+
               exp(n*((rx_I+0.5)*(rx_I+0.5))))/
              (exp(n*((rx_I+3.5)*(rx_I+3.5)))+
               exp(n*((rx_I+2.5)*(rx_I+2.5)))+
               exp(n*((rx_I-1.5)*(rx_I-1.5)))+
               exp(n*((rx_I-0.5)*(rx_I-0.5)))));
    L_u3 = log((exp(n*((rx_I-3.5)*(rx_I-3.5)))+
               exp(n*((rx_I+2.5)*(rx_I+2.5)))+
               exp(n*((rx_I-1.5)*(rx_I-1.5)))+
               exp(n*((rx_I+0.5)*(rx_I+0.5))))/
              (exp(n*((rx_I+3.5)*(rx_I+3.5)))+
               exp(n*((rx_I-2.5)*(rx_I-2.5)))+
               exp(n*((rx_I+1.5)*(rx_I+1.5)))+
               exp(n*((rx_I-0.5)*(rx_I-0.5)))));

    rx_I = rx_Q;

    L_u4 = log((exp(n*((rx_I-3.5)*(rx_I-3.5)))+
               exp(n*((rx_I-2.5)*(rx_I-2.5)))+
               exp(n*((rx_I-1.5)*(rx_I-1.5)))+
               exp(n*((rx_I-0.5)*(rx_I-0.5))))/
              (exp(n*((rx_I+3.5)*(rx_I+3.5)))+
               exp(n*((rx_I+2.5)*(rx_I+2.5)))+
               exp(n*((rx_I+1.5)*(rx_I+1.5)))+
               exp(n*((rx_I+0.5)*(rx_I+0.5)))));
    L_u5 = log((exp(n*((rx_I-3.5)*(rx_I-3.5)))+
               exp(n*((rx_I-2.5)*(rx_I-2.5)))+
               exp(n*((rx_I+1.5)*(rx_I+1.5)))+
               exp(n*((rx_I+0.5)*(rx_I+0.5))))/
              (exp(n*((rx_I+3.5)*(rx_I+3.5)))+
               exp(n*((rx_I+2.5)*(rx_I+2.5)))+
               exp(n*((rx_I-1.5)*(rx_I-1.5)))+
               exp(n*((rx_I-0.5)*(rx_I-0.5)))));
    L_u6 = log((exp(n*((rx_I-3.5)*(rx_I-3.5)))+
               exp(n*((rx_I+2.5)*(rx_I+2.5)))+
               exp(n*((rx_I-1.5)*(rx_I-1.5)))+
               exp(n*((rx_I+0.5)*(rx_I+0.5))))/
              (exp(n*((rx_I+3.5)*(rx_I+3.5)))+
               exp(n*((rx_I-2.5)*(rx_I-2.5)))+
               exp(n*((rx_I+1.5)*(rx_I+1.5)))+
               exp(n*((rx_I-0.5)*(rx_I-0.5)))));

    D1_data[i]     = L_u1;
    D1_data[i+1]   = L_u2;
    D1_data[i+2]   = L_u4;
    D1_data[i+3]   = L_u5;
    D1_parity[i]   = L_u3;
    D1_parity[i+1] = 0.0;
    D1_parity[i+2] = 0.0;
    D1_parity[i+3] = 0.0;
    D2_parity[i]   = L_u6;
    D2_parity[i+1] = 0.0;
    D2_parity[i+2] = 0.0;
    D2_parity[i+3] = 0.0;

    i = i + 4;
  }
/*
 * interleave data:
```

```
     */
    r_ileav(D1_data, rule);

#endif


#ifdef R46_64QAM_IQ_Gray_Map
    /* Option1: used in "Parallel Concatenated Trellis Coded Modulation" ICC'96
     * Channel: I = (u1, u2, u3), Q = (u4, u5, u6) defined using Gray mapping:
     * u1 & u4 are MSBs and u3 & u6 are LSBs:
     *       010---011---001---000---100---101---111---110
     *     -3.5  -2.5  -1.5  -0.5   0.5   1.5   2.5   3.5
     * where:
     *       u1 = d0
     *       u2 = d1
     *       u3 = p0 parity from ENC_V
     *       u4 = d2
     *       u5 = d3
     *       u6 = q0 parity from ENC_H
     *
     * INT_SIZE = multiple of 4
     */

    n   = (-1.0) / (2 * SIGMA_23_8AM * SIGMA_23_8AM);

    /*
     * deinterleave data:
     */
    for(i = 0; i < INT_SIZE; i++)
      data_d[i] = data[i];
    r_deileava(data_d, rule);


    for(i = 0; i < INT_SIZE;)
      {
        /* Puncturing patern is:
         * d0, d1, d2, d3,...
         * p0,  0,  0,  0,...
         * q0,  0,  0,  0,...
         */

        u1   = data_d[i];
        u2   = data_d[i+1];
        u3   = Enc1[i];
        tx   = 2*u1 - 2*u2 + 4*u1*u2 - 1.0 + (((2*u1-1)*(2*u2-1))<0?(u3-0.5):(0.5-u3));
        rx   = tx + SIGMA_23_8AM * gasdev();
        L_u1 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                    exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                   (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                    exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));

        L_u2 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                    exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                   (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                    exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

        L_u3 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                    exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
                   (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                    exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));
        u1   = data_d[i+2];
        u2   = data_d[i+3];
        u3   = Enc2[i];
        tx   = 2*u1 - 2*u2 + 4*u1*u2 - 1.0 + (((2*u1-1)*(2*u2-1))<0?(u3-0.5):(0.5-u3));
        rx   = tx + SIGMA_23_8AM * gasdev();
        L_u4 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                    exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                   (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                    exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));

        L_u5 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
```

```
                    exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                   (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                    exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

        L_u6 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                    exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
                   (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                    exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));

        D1_data[i]     = L_u1;
        D1_data[i+1]   = L_u2;
        D1_data[i+2]   = L_u4;
        D1_data[i+3]   = L_u5;
        D1_parity[i]   = L_u3;
        D1_parity[i+1] = 0.0;
        D1_parity[i+2] = 0.0;
        D1_parity[i+3] = 0.0;
        D2_parity[i]   = L_u6;
        D2_parity[i+1] = 0.0;
        D2_parity[i+2] = 0.0;
        D2_parity[i+3] = 0.0;

        i = i + 4;

      }
    /*
     * interleave data:
     */
    r_ileav(D1_data, rule);

#endif


/*mio*/
#ifdef R24_4QAM
    /*
     * Channel:  we transmit two 2-AM symbols to emulate a 4-QAM symbol.
     * 2 info bits and 2 parity bits are mapped to 2 4-QAM symbols which in
     * turn are simulated as 4 2-AM symbols to achieve 1bit/s/Hz
     *
     * INT_SIZE to be a multiple of 2
     */

    n   = (-1.0) / (2 * SIGMA_24_4QAM * SIGMA_24_4QAM);
    for(i = 0; i < INT_SIZE; i++)
      {
        /* symbol 1 */
        d0  = data[i];
        tx   = d0 - 0.5;
        rx   = tx + SIGMA_24_4QAM * gasdev();
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))) /
                   (exp(n*(rx+0.5)*(rx+0.5))));
        D1_data[i]   = L_d0;

        /* symbol 2 */
        d0   = Enc1[i];
        tx   = d0 - 0.5;
        rx   = tx + SIGMA_24_4QAM * gasdev();
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))) /
                   (exp(n*(rx+0.5)*(rx+0.5))));
        D1_parity[i] = L_d0;

        /* symbol 3 */
        d0   = data[i+1];
        tx   = d0 - 0.5;
        rx   = tx + SIGMA_24_4QAM * gasdev();
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))) /
                   (exp(n*(rx+0.5)*(rx+0.5))));
        D1_data[i+1] = L_d0;

        /* symbol 4 */
```

```
        d0   = Enc2[i+1];
        tx   = d0 - 0.5;
        rx   = tx + SIGMA_24_4QAM * gasdev();
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))) /
                   (exp(n*(rx+0.5)*(rx+0.5))));
        D2_parity[i+1]   = L_d0;
        D1_parity[i+1]   = 0.0;
        D2_parity[i]   = 0.0;
        i = i+1;
      }
#endif

/*mio*/
#ifdef R26_4QAM
    /*
     * Channel:  we transmit two 2-AM symbols to emulate a 4-QAM symbol.
     * 2 info bits and 4 parity bits are mapped to 3 4-QAM symbols which in
     * turn are simulated as 6 2-AM symbols to achieve 1bit/s/Hz
     *
     * INT_SIZE to be a multiple of 2
     */

    n   = (-1.0) / (2 * SIGMA_26_4QAM * SIGMA_26_4QAM);
    for(i = 0; i < INT_SIZE; i++)
      {
        /* symbol 1 */
        d0  = data[i];
        tx   = d0 - 0.5;
        rx   = tx + SIGMA_26_4QAM * gasdev();
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))) /
                   (exp(n*(rx+0.5)*(rx+0.5))));
        D1_data[i]   = L_d0;

        /* symbol 2 */
        d0   = Enc1[i];
        tx   = d0 - 0.5;
        rx   = tx + SIGMA_26_4QAM * gasdev();
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))) /
                   (exp(n*(rx+0.5)*(rx+0.5))));
        D1_parity[i] = L_d0;

        /* symbol 3 */
        d0   = Enc2[i];
        tx   = d0 - 0.5;
        rx   = tx + SIGMA_26_4QAM * gasdev();
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))) /
                   (exp(n*(rx+0.5)*(rx+0.5))));
        D2_parity[i] = L_d0;

        /* symbol 4 */
        d0  = data[i+1];
        tx   = d0 - 0.5;
        rx   = tx + SIGMA_26_4QAM * gasdev();
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))) /
                   (exp(n*(rx+0.5)*(rx+0.5))));
        D1_data[i+1]   = L_d0;

        /* symbol 5 */
        d0   = Enc1[i+1];
        tx   = d0 - 0.5;
        rx   = tx + SIGMA_26_4QAM * gasdev();
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))) /
                   (exp(n*(rx+0.5)*(rx+0.5))));
        D1_parity[i+1] = L_d0;

        /* symbol 6 */
        d0   = Enc2[i+1];
        tx   = d0 - 0.5;
        rx   = tx + SIGMA_26_4QAM * gasdev();
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))) /
                   (exp(n*(rx+0.5)*(rx+0.5))));
```

```
        D2_parity[i+1] = L_d0;
        i = i+1;
      }
#endif

/*mio*/
#ifdef R46_8QAM
    /*
     * I dimension:
     * d0 is MSB and d1 is LSB in a 4-AM:(d0,d1):
     *       01----00----10----11
     *     -1.5  -0.5   0.5   1.5
     * Q dimension:
     * d0 is MSB in a 2-AM:(d0):
     *       0-----1
     *     -0.5   0.5
     *
     *
     * We transmit one 4A-M symbol and one 2-AM symbol to emulate a 32QAM symbol.
     * 4 info bits and 2 parity bits are mapped to 2 8QAM symbols.
     *
     * INT_SIZE to be a multiple of 4
     */

    for(i = 0; i < INT_SIZE; i++)
      {
        /* symbol 1: 4AM */
        d0 = data[i];
        d1 = Enc1[i];
        tx   = d0 - d1 + 2*d0*d1 - 0.5;
        rx   = tx + SIGMA_4AM_of_46_8QAM * gasdev();
        n    = (-1.0) / (2 * SIGMA_4AM_of_46_8QAM * SIGMA_4AM_of_46_8QAM);
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))) /
                   (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5))));
        L_d1 = log((exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx-1.5)*(rx-1.5))) /
                   (exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx+0.5)*(rx+0.5))));
        D1_data[i]   = L_d0;
        D1_parity[i] = L_d1;

        /* symbol 2: 2AM */
        d0 = data[i+1];
        tx   = d0 - 0.5;
        rx   = tx + SIGMA_2AM_of_46_8QAM * gasdev();
        n    = (-1.0) / (2 * SIGMA_2AM_of_46_8QAM * SIGMA_2AM_of_46_8QAM);
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))) /
                   (exp(n*(rx+0.5)*(rx+0.5))));
        D1_data[i+1]   = L_d0;

        /* symbol 3: 4AM */
        d0 = data[i+2];
        d1 = Enc2[i+2];
        tx   = d0 - d1 + 2*d0*d1 - 0.5;
        rx   = tx + SIGMA_4AM_of_46_8QAM * gasdev();
        n    = (-1.0) / (2 * SIGMA_4AM_of_46_8QAM * SIGMA_4AM_of_46_8QAM);
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))) /
                   (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5))));
        L_d1 = log((exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx-1.5)*(rx-1.5))) /
                   (exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx+0.5)*(rx+0.5))));
        D1_data[i+2]   = L_d0;
        D2_parity[i+2] = L_d1;

        /* symbol 2: 4AM */
        d0 = data[i+3];
        tx   = d0 - 0.5;
        rx   = tx + SIGMA_2AM_of_46_8QAM * gasdev();
        n    = (-1.0) / (2 * SIGMA_2AM_of_46_8QAM * SIGMA_2AM_of_46_8QAM);
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))) /
                   (exp(n*(rx+0.5)*(rx+0.5))));
        D1_data[i+3]   = L_d0;
      D1_parity[i+1]   = 0.0;
      D1_parity[i+2]   = 0.0;
```

```
    D1_parity[i+3]   = 0.0;
    D2_parity[i]   = 0.0;
    D2_parity[i+1]   = 0.0;
    D2_parity[i+3]   = 0.0;

       i = i+3;
     }
#endif

/*mio*/
#ifdef R26_8QAM
    /*
     * I dimension:
     * d0 is MSB and d1 is LSB in a 4-AM:(d0,d1):
     *       01----00----10----11
     *     -1.5  -0.5   0.5   1.5
     * Q dimension:
     * d0 is MSB in a 2-AM:(d0):
     *       0-----1
     *     -0.5   0.5
     *
     *
     * We transmit one 4A-M symbol and one 2-AM symbol to emulate a 8QAM symbol.
     * 2 info bits and 4 parity bits are mapped to 2 8QAM symbols.
     *
     * INT_SIZE to be a multiple of 2
     */

    for(i = 0; i < INT_SIZE; i++)
      {
    /* symbol 1: 4AM */

       d0 = data[i];
       d1 = Enc1[i];
       tx   = d0 - d1 + 2*d0*d1 - 0.5;
       rx   = tx + SIGMA_4AM_of_26_8QAM * gasdev();
       n   = (-1.0) / (2 * SIGMA_4AM_of_26_8QAM * SIGMA_4AM_of_26_8QAM);
       L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))) /
                  (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5))));
       L_d1 = log((exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx-1.5)*(rx-1.5))) /
                  (exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx+0.5)*(rx+0.5))));
       D1_data[i]   = L_d0;
       D1_parity[i] = L_d1;

    /* symbol 2: 2AM */

       d0 = Enc2[i];
       tx   = d0 - 0.5;
       rx   = tx + SIGMA_2AM_of_26_8QAM * gasdev();
       n   = (-1.0) / (2 * SIGMA_2AM_of_26_8QAM * SIGMA_2AM_of_26_8QAM);
       L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))) /
                  (exp(n*(rx+0.5)*(rx+0.5))));
       D2_parity[i]   = L_d0;

       /* symbol 3: 4AM */

       d0 = Enc1[i+1];
       d1 = Enc2[i+1];
       tx   = d0 - d1 + 2*d0*d1 - 0.5;
       rx   = tx + SIGMA_4AM_of_26_8QAM * gasdev();
       n   = (-1.0) / (2 * SIGMA_4AM_of_26_8QAM * SIGMA_4AM_of_26_8QAM);
       L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))) /
                  (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5))));
       L_d1 = log((exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx-1.5)*(rx-1.5))) /
                  (exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx+0.5)*(rx+0.5))));
       D1_parity[i+1] = L_d0;
       D2_parity[i+1] = L_d1;

    /* symbol 4: 2AM */

       d0 = data[i+1];
```

```
        tx   = d0 - 0.5;
        rx   = tx + SIGMA_2AM_of_26_8QAM * gasdev();
        n    = (-1.0) / (2 * SIGMA_2AM_of_26_8QAM * SIGMA_2AM_of_26_8QAM);
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))) /
                   (exp(n*(rx+0.5)*(rx+0.5))));
        D1_data[i+1]   = L_d0;
        i=i+1;
        }
#endif

/*mio*/
#ifdef R13_8QAM
    /*
     * I dimension:
     * d0 is MSB and d1 is LSB in a 4-AM:(d0,d1):
     *       01----00----10----11
     *     -1.5  -0.5   0.5   1.5
     * Q dimension:
     * d0 is MSB in a 2-AM:(d0):
     *       0-----1
     *     -0.5   0.5
     *
     *
     * We transmit one 4A-M symbol and one 2-AM symbol to emulate a 8QAM symbol.
     * 1 info bits and 2 parity bits are mapped to 1 8QAM symbols.
     *
     * INT_SIZE to be a multiple of 1
     */

    for(i = 0; i < INT_SIZE; i++)
      {
    /* symbol 1: 4AM */

        d0 = data[i];
        d1 = Enc1[i];
        tx   = d0 - d1 + 2*d0*d1 - 0.5;
        rx   = tx + SIGMA_4AM_of_13_8QAM * gasdev();
        n    = (-1.0) / (2 * SIGMA_4AM_of_13_8QAM * SIGMA_4AM_of_13_8QAM);
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))) /
                   (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5))));
        L_d1 = log((exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx-1.5)*(rx-1.5))) /
                   (exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx+0.5)*(rx+0.5))));
        D1_data[i]   = L_d0;
        D1_parity[i] = L_d1;

    /* symbol 2: 2AM */

        d0 = Enc2[i];
        tx   = d0 - 0.5;
        rx   = tx + SIGMA_2AM_of_13_8QAM * gasdev();
        n    = (-1.0) / (2 * SIGMA_2AM_of_13_8QAM * SIGMA_2AM_of_13_8QAM);
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))) /
                   (exp(n*(rx+0.5)*(rx+0.5))));
        D2_parity[i]   = L_d0;

        }
#endif

/*mio*/
#ifdef R412_16QAM
    /*
     * Channel:  we transmit two 4-AM symbols to emulate a 16-QAM symbol.
     * 4 info bits and 8 parity bits are mapped to 3 16-QAM symbols which in
     * turn are simulated as 6 4-AM symbols to achieve 3bit/s/Hz
     * d0 is MSB and d1 is LSB in a 4-AM:(d0,d1) =   01----00--|--10----11
     *                                              -1.5  -0.5    0.5   1.5
     * INT_SIZE to be a multiple of 4
     */

    n    = (-1.0) / (2 * SIGMA_412_16QAM * SIGMA_412_16QAM);
    for(i = 0; i < INT_SIZE; i++)
```

```
{
  /* symbol 1 */
  d0  = data[i];
  d1  = Enc1[i];
  tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0;
  rx   = tx + SIGMA_412_16QAM * gasdev();
  L_d0 = log((exp(n*(rx-1)*(rx-1))+exp(n*(rx-3)*(rx-3))) /
             (exp(n*(rx+1)*(rx+1))+exp(n*(rx+3)*(rx+3))));
  L_d1 = log((exp(n*(rx+3)*(rx+3))+exp(n*(rx-3)*(rx-3))) /
             (exp(n*(rx-1)*(rx-1))+exp(n*(rx+1)*(rx+1))));
  D1_data[i]   = L_d0;
  D1_parity[i] = L_d1;

  /* symbol 2 */
  d0   = data[i+1];
  d1   = Enc1[i+1];
  tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0;
  rx   = tx + SIGMA_412_16QAM * gasdev();
  L_d0 = log((exp(n*(rx-1)*(rx-1))+exp(n*(rx-3)*(rx-3))) /
             (exp(n*(rx+1)*(rx+1))+exp(n*(rx+3)*(rx+3))));
  L_d1 = log((exp(n*(rx+3)*(rx+3))+exp(n*(rx-3)*(rx-3))) /
             (exp(n*(rx-1)*(rx-1))+exp(n*(rx+1)*(rx+1))));
  D1_data[i+1] = L_d0;
  D1_parity[i+1] = L_d1;

  /* symbol 3 */
  d0   = Enc2[i];
  d1   = Enc2[i+1];
  tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0;
  rx   = tx + SIGMA_412_16QAM * gasdev();
  L_d0 = log((exp(n*(rx-1)*(rx-1))+exp(n*(rx-3)*(rx-3))) /
             (exp(n*(rx+1)*(rx+1))+exp(n*(rx+3)*(rx+3))));
  L_d1 = log((exp(n*(rx+3)*(rx+3))+exp(n*(rx-3)*(rx-3))) /
             (exp(n*(rx-1)*(rx-1))+exp(n*(rx+1)*(rx+1))));
  D2_parity[i]   = L_d0;
  D2_parity[i+1] = L_d1;

  /* symbol 4 */
  d0   = data[i+2];
  d1   = Enc1[i+2];
  tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0;
  rx   = tx + SIGMA_412_16QAM * gasdev();
  L_d0 = log((exp(n*(rx-1)*(rx-1))+exp(n*(rx-3)*(rx-3))) /
             (exp(n*(rx+1)*(rx+1))+exp(n*(rx+3)*(rx+3))));
  L_d1 = log((exp(n*(rx+3)*(rx+3))+exp(n*(rx-3)*(rx-3))) /
             (exp(n*(rx-1)*(rx-1))+exp(n*(rx+1)*(rx+1))));
  D1_data[i+2]   = L_d0;
  D1_parity[i+2] = L_d1;

    /* symbol 5 */
  d0   = Enc2[i+2];
  d1   = Enc2[i+3];
  tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0;
  rx   = tx + SIGMA_412_16QAM * gasdev();
  L_d0 = log((exp(n*(rx-1)*(rx-1))+exp(n*(rx-3)*(rx-3))) /
             (exp(n*(rx+1)*(rx+1))+exp(n*(rx+3)*(rx+3))));
  L_d1 = log((exp(n*(rx+3)*(rx+3))+exp(n*(rx-3)*(rx-3))) /
             (exp(n*(rx-1)*(rx-1))+exp(n*(rx+1)*(rx+1))));
  D2_parity[i+2] = L_d0;
  D2_parity[i+3] = L_d1;

  /* symbol 6 */
  d0   = data[i+3];
  d1   = Enc1[i+3];
  tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0;
  rx   = tx + SIGMA_412_16QAM * gasdev();
  L_d0 = log((exp(n*(rx-1)*(rx-1))+exp(n*(rx-3)*(rx-3))) /
             (exp(n*(rx+1)*(rx+1))+exp(n*(rx+3)*(rx+3))));
  L_d1 = log((exp(n*(rx+3)*(rx+3))+exp(n*(rx-3)*(rx-3))) /
             (exp(n*(rx-1)*(rx-1))+exp(n*(rx+1)*(rx+1))));
  D1_data[i+3]   = L_d0;
```

```
        D1_parity[i+3] = L_d1;

                i = i+3;
      }
#endif

/*mio*/
#ifdef R515_32QAM
    /*
     * I dimension:
     * d0 is MSB and d2 is LSB in 8-AM:(d0,d1,d2):
     *       010---011---001---000---100---101---111---110
     *      -3.5  -2.5  -1.5  -0.5   0.5   1.5   2.5   3.5
     * Q dimension:
     * d0 is MSB and d1 is LSB in a 4-AM:(d0,d1):
     *       01----00----10----11
     *     -1.5  -0.5   0.5   1.5
     *
     *
     * We transmit one 8AM symbol and one 4AM symbol to emulate a 32QAM symbol.
     * 5 info bits and 10 parity bits are mapped to 3 32QAM symbols.
     *
     * INT_SIZE to be a multiple of 5
     */

    for(i = 0; i < INT_SIZE; i++)
      {
        /* symbol 1: 8AM */
    d0  = data[i];
    d1  = Enc1[i];
        d2  = Enc2[i];
        tx  = 2*d0 - 2*d1 + 4*d0*d1 - 1.0 + (((2*d0-1)*(2*d1-1))<0?(d2-0.5):(0.5-d2));
        rx  = tx + SIGMA_8AM_of_515_32QAM * gasdev();
        n   = (-1.0) / (2 * SIGMA_8AM_of_515_32QAM * SIGMA_8AM_of_515_32QAM);
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                    exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                   (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                    exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));

        L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                    exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                   (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                    exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

        L_d2 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                    exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
                   (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                    exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));
    D1_data[i]     = L_d0;
    D1_parity[i]   = L_d1;
        D2_parity[i]   = L_d2;

        /* symbol 2: 4AM */
        d0 = data[i+1];
        d1 = Enc1[i+1];
        tx   = d0 - d1 + 2*d0*d1 - 0.5;
        rx   = tx + SIGMA_4AM_of_515_32QAM * gasdev();
        n   = (-1.0) / (2 * SIGMA_4AM_of_515_32QAM * SIGMA_4AM_of_515_32QAM);
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))) /
                   (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5))));
        L_d1 = log((exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx-1.5)*(rx-1.5))) /
                   (exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx+0.5)*(rx+0.5))));
        D1_data[i+1]   = L_d0;
        D2_parity[i+1] = L_d1;

        /* symbol 3: 8AM */
    d0   = data[i+2];
    d1   = Enc1[i+2];
        d2   = Enc2[i+1];
        tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0 + (((2*d0-1)*(2*d1-1))<0?(d2-0.5):(0.5-d2));
        rx  = tx + SIGMA_8AM_of_515_32QAM * gasdev();
```

```
    n   = (-1.0) / (2 * SIGMA_8AM_of_515_32QAM * SIGMA_8AM_of_515_32QAM);
    L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
               exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
              (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
               exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));

    L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
               exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
              (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
               exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

    L_d2 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
               exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
              (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
               exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));
D1_data[i+2]   = L_d0;
D1_parity[i+2] = L_d1;
    D2_parity[i+1] = L_d2;

    /* symbol 4: 4AM */
    d0 = data[i+3];
    d1 = Enc2[i+2];
    tx   = d0 - d1 + 2*d0*d1 - 0.5;
    rx   = tx + SIGMA_4AM_of__515_32QAM * gasdev();
    n   = (-1.0) / (2 * SIGMA_4AM_of_515_32QAM * SIGMA_4AM_of_515_32QAM);
    L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))) /
              (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5))));
    L_d1 = log((exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx-1.5)*(rx-1.5))) /
              (exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx+0.5)*(rx+0.5))));
    D1_data[i+3]   = L_d0;
    D2_parity[i+2] = L_d1;

    /* symbol 5: 8AM */
d0   = data[i+4];
d1   = Enc1[i+3];
    d2   = Enc2[i+3];
    tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0 + (((2*d0-1)*(2*d1-1))<0?(d2-0.5):(0.5-d2));
    rx  = tx + SIGMA_8AM_of_515_32QAM * gasdev();
    n   = (-1.0) / (2 * SIGMA_8AM_of_515_32QAM * SIGMA_8AM_of_515_32QAM);
    L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
               exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
              (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
               exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));

    L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
               exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
              (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
               exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

    L_d2 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
               exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
              (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
               exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));
D1_data[i+4]   = L_d0;
D1_parity[i+3] = L_d1;
    D2_parity[i+3] = L_d2;

    /* symbol 4: 4AM */
    d0 = Enc1[i+4];
    d1 = Enc2[i+4];
    tx   = d0 - d1 + 2*d0*d1 - 0.5;
    rx   = tx + SIGMA_4AM_of__515_32QAM * gasdev();
    n   = (-1.0) / (2 * SIGMA_4AM_of_515_32QAM * SIGMA_4AM_of_515_32QAM);
    L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))) /
              (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5))));
    L_d1 = log((exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx-1.5)*(rx-1.5))) /
              (exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx+0.5)*(rx+0.5))));
    D1_parity[i+4] = L_d0;
    D2_parity[i+4] = L_d1;

    i = i+4;
```

```
    }
#endif

/*mio*/
#ifdef R26_64QAM
    /*
     * Channel:
     * d0 is MSB and d2 is LSB in 8AM:(d0,d1,d2):
     *       010---011---001---000---100---101---111---110
     *      -3.5  -2.5  -1.5  -0.5   0.5   1.5   2.5   3.5
     */
    /*
     * Channel:  we transmit two 8AM symbols to emulate a 64QAM symbol.
     * 2 info bits and 4 parity bits are mapped to 1 64QAM symbols which in
     * turn are simulated as 2 8AM symbols to achieve 2bit/s/Hz.
     *
     * INT_SIZE to be a multiple of 2
     */
    n   = (-1.0) / (2 * SIGMA_26_64QAM * SIGMA_26_64QAM);
    for(i = 0; i < INT_SIZE; i++)
      {
    /* symbol 1 */

        d0  = data[i];
    d1  = Enc1[i];
        d2  = Enc2[i];
        tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0 + (((2*d0-1)*(2*d1-1))<0?(d2-0.5):(0.5-d2));
    rx   = tx + SIGMA_26_64QAM * gasdev();
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                    exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                   (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                    exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));

        L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                    exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                   (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                    exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

        L_d2 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                    exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
                   (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                    exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));
    D1_data[i]     = L_d0;
    D1_parity[i]   = L_d1;
        D2_parity[i]   = L_d2;

    /* symbol 2 */

        d0   = data[i+1];
    d1   = Enc1[i+1];
        d2   = Enc2[i+1];
        tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0 + (((2*d0-1)*(2*d1-1))<0?(d2-0.5):(0.5-d2));
    rx   = tx + SIGMA_26_64QAM * gasdev();
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                    exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                   (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                    exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));

        L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                    exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                   (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                    exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

        L_d2 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                    exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
                   (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                    exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));
    D1_data[i+1]     = L_d0;
    D1_parity[i+1]   = L_d1;
    D2_parity[i+1]   = L_d2;
        i = i+1;
```

```
      }
#endif

/*mio*/
#ifdef R36_64QAM
    /*
     * Channel:
     * d0 is MSB and d2 is LSB in 8AM:(d0,d1,d2):
     *       010---011---001---000---100---101---111---110
     *      -3.5  -2.5  -1.5  -0.5   0.5   1.5   2.5   3.5
     */
    /*
     * Channel:  we transmit two 8AM symbols to emulate a 64QAM symbol.
     * 6 info bits and 6 parity bits are mapped to 2 64QAM symbols which in
     * turn are simulated as 4 8AM symbols to achieve 2bit/s/Hz.
     *
     * INT_SIZE to be a multiple of 6
     */
    n   = (-1.0) / (2 * SIGMA_36_64QAM * SIGMA_36_64QAM);
    for(i = 0; i < INT_SIZE; i++)
      {
    /* symbol 1 */

       d0  = data[i];
    d1  = data[i+1];
       d2  = Enc1[i];
       tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0 + (((2*d0-1)*(2*d1-1))<0?(d2-0.5):(0.5-d2));
    rx   = tx + SIGMA_36_64QAM * gasdev();
       L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                  exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                 (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                  exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));

       L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                  exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                 (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                  exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

       L_d2 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                  exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
                 (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                  exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));
    D1_data[i]      = L_d0;
    D1_data[i+1]    = L_d1;
       D1_parity[i]    = L_d2;

    /* symbol 2 */

       d0   = data[i+2];
    d1   = Enc1[i+2];
       d2   = Enc2[i+1];
       tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0 + (((2*d0-1)*(2*d1-1))<0?(d2-0.5):(0.5-d2));
    rx   = tx + SIGMA_36_64QAM * gasdev();
       L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                  exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                 (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                  exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));

       L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                  exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                 (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                  exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

       L_d2 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                  exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
                 (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                  exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));
    D1_data[i+2]      = L_d0;
    D1_parity[i+2]    = L_d1;
    D2_parity[i+1]    = L_d2;
```

```
    /* symbol 3 */

        d0  = data[i+3];
    d1  = data[i+4];
        d2  = Enc2[i+3];
        tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0 + (((2*d0-1)*(2*d1-1))<0?(d2-0.5):(0.5-d2));
    rx   = tx + SIGMA_36_64QAM * gasdev();
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                   exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                  (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                   exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));

        L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                   exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                  (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                   exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

        L_d2 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                   exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
                  (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                   exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));
    D1_data[i+3]      = L_d0;
    D1_data[i+4]      = L_d1;
        D2_parity[i+3]    = L_d2;

    /* symbol 2 */

        d0   = data[i+5];
    d1   = Enc1[i+4];
        d2   = Enc2[i+5];
        tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0 + (((2*d0-1)*(2*d1-1))<0?(d2-0.5):(0.5-d2));
    rx   = tx + SIGMA_36_64QAM * gasdev();
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                   exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                  (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                   exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));

        L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                   exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                  (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                   exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

        L_d2 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                   exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
                  (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                   exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));
    D1_data[i+5]      = L_d0;
    D1_parity[i+4]    = L_d1;
    D2_parity[i+5]    = L_d2;
    D2_parity[i]      = 0.0;
    D1_parity[i+1]    = 0.0;
    D2_parity[i+2]    = 0.0;
    D1_parity[i+3]    = 0.0;
    D2_parity[i+4]    = 0.0;
    D1_parity[i+5]    = 0.0;
        i = i+5;
      }
#endif

/*mio*/
#ifdef R721_128QAM
    /*
     * Q dimension:
     * d0 is MSB and d2 is LSB in 8-AM:(d0,d1,d2):
     *       010---011---001---000---100---101---111---110
     *      -3.5  -2.5  -1.5  -0.5   0.5   1.5   2.5   3.5
     * I dimension:
     * d0 is MSB and d3 is LSB in 16AM:(d0,d1,d2,d3):
     *
     *       0010---0011---0001---0000---0100---0101---0111---0110
     *       -7.5   -6.5   -5.5   -4.5   -3.5   -2.5   -1.5   -0.5
```

```
 *
 *       1010---1011---1001---1000---1100---1101---1111---1110
 *        7.5    6.5    5.5    4.5    3.5    2.5    1.5    0.5
 *
 * INT_SIZE to be a multiple of 7
 */

for(i = 0; i < INT_SIZE; i++)
  {

    /* symbol 1 Q dimension: 8AM */

    d0  = data[i+2];
d1  = Enc1[i+1];
    d2  = Enc2[i+1];
    tx  = 2*d0 - 2*d1 + 4*d0*d1 - 1.0 + (((2*d0-1)*(2*d1-1))<0?(d2-0.5):(0.5-d2));
     rx  = tx + SIGMA_8AM_of_721_128QAM * gasdev();
    n   = (-1.0) / (2 * SIGMA_8AM_of_721_128QAM * SIGMA_8AM_of_721_128QAM);
    L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
               exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
              (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
               exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));

    L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
               exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
              (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
               exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

    L_d2 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
               exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
              (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
               exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));
D1_data[i+2]      = L_d0;
D1_parity[i+1]    = L_d1;
    D2_parity[i+1]    = L_d2;

/* symbol 2 I dimension: 16AM */

    d0 = data[i];
d1 = data[i+1];
d2 = Enc1[i];
    d3 = Enc2[i];
    tx = 2*d1 - 2*d2 + 4*d1*d2 - 1.0 + (((2*d1-1)*(2*d2-1))<0?(d3-0.5):(0.5-d3));
    tx = (d0 == 0 ? (tx - 4): (4 - tx));
     rx = tx + SIGMA_16AM_of_721_128QAM * gasdev();
    n  = (-1.0) / (2 * SIGMA_16AM_of_721_128QAM * SIGMA_16AM_of_721_128QAM);
    L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
               exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
               exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
               exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
              (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
               exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
               exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
               exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

    L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
               exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
               exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
               exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
              (exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
               exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
               exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
               exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

    L_d2 = log((exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+6.5)*(rx+6.5)) +
               exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
               exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
               exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
              (exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+4.5)*(rx+4.5)) +
               exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
               exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
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```
                exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5))));

    L_d3 = log((exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+6.5)*(rx+6.5)) +
                exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-5.5)*(rx-5.5)))/
               (exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+4.5)*(rx+4.5)) +
                exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-7.5)*(rx-7.5))));

D1_data[i]      = L_d0;
D1_data[i+1]    = L_d1;
    D1_parity[i]    = L_d2;
    D2_parity[i]    = L_d3;

/* symbol 3 Q dimension: 8AM */

    d0  = data[i+4];
d1  = Enc1[i+4];
    d2  = Enc2[i+3];
    tx  = 2*d0 - 2*d1 + 4*d0*d1 - 1.0 + (((2*d0-1)*(2*d1-1))<0?(d2-0.5):(0.5-d2));
rx  = tx + SIGMA_8AM_of_721_128QAM * gasdev();
    n   = (-1.0) / (2 * SIGMA_8AM_of_721_128QAM * SIGMA_8AM_of_721_128QAM);
    L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
               (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));

    L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
               (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

    L_d2 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
               (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));
D1_data[i+4]      = L_d0;
D1_parity[i+4]    = L_d1;
    D2_parity[i+3]    = L_d2;

/* symbol 4 I dimension: 16AM */

    d0 = data[i+3];
d1 = Enc1[i+3];
d2 = Enc1[i+2];
    d3 = Enc2[i+2];
    tx = 2*d1 - 2*d2 + 4*d1*d2 - 1.0 + (((2*d1-1)*(2*d2-1))<0?(d3-0.5):(0.5-d3));
    tx = (d0 == 0 ? (tx - 4): (4 - tx));
rx = tx + SIGMA_16AM_of_721_128QAM * gasdev();
    n  = (-1.0) / (2 * SIGMA_16AM_of_721_128QAM * SIGMA_16AM_of_721_128QAM);
    L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
               (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
                exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

    L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
               (exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
                exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

    L_d2 = log((exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+6.5)*(rx+6.5)) +
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                exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
               (exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+4.5)*(rx+4.5)) +
                exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5))));

    L_d3 = log((exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+6.5)*(rx+6.5)) +
                exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-5.5)*(rx-5.5)))/
               (exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+4.5)*(rx+4.5)) +
                exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-7.5)*(rx-7.5))));

D1_data[i+3]      = L_d0;
D1_parity[i+3]    = L_d1;
    D1_parity[i+2]    = L_d2;
    D2_parity[i+2]    = L_d3;

/* symbol 5 Q dimension: 8AM */

    d0  = data[i+6];
d1  = Enc1[i+6];
    d2  = Enc2[i+6];
    tx  = 2*d0 - 2*d1 + 4*d0*d1 - 1.0 + (((2*d0-1)*(2*d1-1))<0?(d2-0.5):(0.5-d2));
rx  = tx + SIGMA_8AM_of_721_128QAM * gasdev();
    n   = (-1.0) / (2 * SIGMA_8AM_of_721_128QAM * SIGMA_8AM_of_721_128QAM);
    L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
               (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));

    L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
               (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

    L_d2 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
               (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));
D1_data[i+6]      = L_d0;
D1_parity[i+6]    = L_d1;
    D2_parity[i+6]    = L_d2;

/* symbol 6 I dimension: 16AM */

    d0 = data[i+5];
d1 = Enc1[i+5];
d2 = Enc2[i+5];
    d3 = Enc2[i+4];
    tx = 2*d1 - 2*d2 + 4*d1*d2 - 1.0 + (((2*d1-1)*(2*d2-1))<0?(d3-0.5):(0.5-d3));
    tx = (d0 == 0 ? (tx - 4): (4 - tx));
rx = tx + SIGMA_16AM_of_721_128QAM * gasdev();
    n  = (-1.0) / (2 * SIGMA_16AM_of_721_128QAM * SIGMA_16AM_of_721_128QAM);
    L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
               (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
                exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

    L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
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                    (exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                     exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
                     exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                     exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

        L_d2 = log((exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+6.5)*(rx+6.5)) +
                    exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                    exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                    exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
                   (exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+4.5)*(rx+4.5)) +
                    exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                    exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                    exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5))));

        L_d3 = log((exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+6.5)*(rx+6.5)) +
                    exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                    exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                    exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-5.5)*(rx-5.5)))/
                   (exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+4.5)*(rx+4.5)) +
                    exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                    exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                    exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-7.5)*(rx-7.5))));

    D1_data[i+5]     = L_d0;
    D1_parity[i+5]   = L_d1;
       D2_parity[i+5]   = L_d2;
       D2_parity[i+4]   = L_d3;
       i = i+6;
     }
#endif


/*mio*/
#ifdef R824_256QAM
    /*
     * Channel:
     * d0 is MSB and d3 is LSB in 16AM:(d0,d1,d2,d3):
     *
     *       0010---0011---0001---0000---0100---0101---0111---0110
     *       -7.5   -6.5   -5.5   -4.5   -3.5   -2.5   -1.5   -0.5
     *
     *       1010---1011---1001---1000---1100---1101---1111---1110
     *        7.5    6.5    5.5    4.5    3.5    2.5    1.5    0.5
     *
     * Channel:  we transmit two 16AM symbols to emulate a 256QAM symbol.
     * 8 info bits and 16 parity bits are mapped to 3 256QAM symbols which in
     * turn are simulated as 6 16AM symbols to achieve 8/3bit/s/Hz.
     *
     * INT_SIZE to be a multiple of 8
     */

    n   = (-1.0) / (2 * SIGMA_824_256QAM * SIGMA_824_256QAM);

    /*
     * deinterleave data:
     */
    for(i = 0; i < INT_SIZE; i++)
      data_d[i] = data[i];
    r_deileava(data_d, rule);

    for(i = 0; i < INT_SIZE; i++)
      {
        /* symbol 1 */
    d0 = data_d[i];
    d1 = data_d[i+1];
    d2 = Enc1[i];
       d3 = Enc2[i];
       tx = 2*d1 - 2*d2 + 4*d1*d2 - 1.0 + (((2*d1-1)*(2*d2-1))<0?(d3-0.5):(0.5-d3));
       tx = (d0 == 0 ? (tx - 4): (4 - tx));
       /* Test the mapping to the 16AM constellation:
        * if (i < 500)
```

```
     *  printf("\n(%d%d%d%d) = %f", (int)d0, (int)d1, (int)d2, (int)d3, tx);
     */
rx    = tx + SIGMA_58_256QAM * gasdev();
    L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
               (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
                exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

    L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
               (exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
                exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

    L_d2 = log((exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+6.5)*(rx+6.5)) +
                exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
               (exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+4.5)*(rx+4.5)) +
                exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5))));

    L_d3 = log((exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+6.5)*(rx+6.5)) +
                exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-5.5)*(rx-5.5)))/
               (exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+4.5)*(rx+4.5)) +
                exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-7.5)*(rx-7.5))));

D1_data[i]     = L_d0;
D1_data[i+1]   = L_d1;
    D1_parity[i]   = L_d2;
    D2_parity[i]   = L_d3;

    /* symbol 2 */
d0 = data_d[i+2];
d1 = Enc1[i+2];
    d2 = Enc1[i+1];
    d3 = Enc2[i+1];
    tx = 2*d1 - 2*d2 + 4*d1*d2 - 1.0 + (((2*d1-1)*(2*d2-1))<0?(d3-0.5):(0.5-d3));
    tx = (d0 == 0 ? (tx - 4): (4 - tx));
rx    = tx + SIGMA_824_256QAM * gasdev();
    L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
               (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
                exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

    L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
               (exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
                exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

    L_d2 = log((exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+6.5)*(rx+6.5)) +
```

```
                exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
               (exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+4.5)*(rx+4.5)) +
                exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5))));

    L_d3 = log((exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+6.5)*(rx+6.5)) +
                exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-5.5)*(rx-5.5)))/
               (exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+4.5)*(rx+4.5)) +
                exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-7.5)*(rx-7.5))));
D1_data[i+2]    = L_d0;
D1_parity[i+2] = L_d1;
D1_parity[i+1] = L_d2;
D2_parity[i+1] = L_d3;

    /* symbol 3 */
d0    = data_d[i+3];
d1    = Enc1[i+3];
d2    = Enc2[i+3];
    d3    = Enc1[i+2];
    tx = 2*d1 - 2*d2 + 4*d1*d2 - 1.0 + (((2*d1-1)*(2*d2-1))<0?(d3-0.5):(0.5-d3));
    tx = (d0 == 0 ? (tx - 4): (4 - tx));
rx    = tx + SIGMA_824_256QAM * gasdev();
    L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
               (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
                exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

    L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
               (exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
                exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

    L_d2 = log((exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+6.5)*(rx+6.5)) +
                exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
               (exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+4.5)*(rx+4.5)) +
                exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5))));

    L_d3 = log((exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+6.5)*(rx+6.5)) +
                exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-5.5)*(rx-5.5)))/
               (exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+4.5)*(rx+4.5)) +
                exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-7.5)*(rx-7.5))));
D1_data[i+3]     = L_d0;
D1_parity[i+3]   = L_d1;
D2_parity[i+3]   = L_d2;
    D2_parity[i+2]    = L_d3;

/* symbol 4 */
d0    = data_d[i+4];
```

```
d1   = data_d[i+5];
    d2   = Enc1[i+4];
    d3   = Enc2[i+4];
    tx = 2*d1 - 2*d2 + 4*d1*d2 - 1.0 + (((2*d1-1)*(2*d2-1))<0?(d3-0.5):(0.5-d3));
    tx = (d0 == 0 ? (tx - 4): (4 - tx));
rx   = tx + SIGMA_824_256QAM * gasdev();
    L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
               (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
                exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

    L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
               (exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
                exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

    L_d2 = log((exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+6.5)*(rx+6.5)) +
                exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
               (exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+4.5)*(rx+4.5)) +
                exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5))));

    L_d3 = log((exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+6.5)*(rx+6.5)) +
                exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-5.5)*(rx-5.5)))/
               (exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+4.5)*(rx+4.5)) +
                exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-7.5)*(rx-7.5))));
D1_data[i+4]   = L_d0;
D1_data[i+5]   = L_d1;
    D1_parity[i+4] = L_d2;
    D2_parity[i+4] = L_d3;

    /* symbol 5 */

    d0   = data_d[i+6];
d1   = Enc1[i+6];
d2   = Enc1[i+5];
    d3   = Enc2[i+5];
    tx = 2*d1 - 2*d2 + 4*d1*d2 - 1.0 + (((2*d1-1)*(2*d2-1))<0?(d3-0.5):(0.5-d3));
    tx = (d0 == 0 ? (tx - 4): (4 - tx));
rx   = tx + SIGMA_824_256QAM * gasdev();
    L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
               (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
                exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

    L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
               (exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
                exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
```

```
                exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

    L_d2 = log((exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+6.5)*(rx+6.5)) +
               exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
               exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
               exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
              (exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+4.5)*(rx+4.5)) +
               exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
               exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
               exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5))));

    L_d3 = log((exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+6.5)*(rx+6.5)) +
               exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+2.5)*(rx+2.5)) +
               exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-1.5)*(rx-1.5)) +
               exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-5.5)*(rx-5.5)))/
              (exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+4.5)*(rx+4.5)) +
               exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
               exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5)) +
               exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-7.5)*(rx-7.5))));
D1_data[i+6]     = L_d0;
D1_parity[i+6]   = L_d1;
D1_parity[i+5]   = L_d2;
   D2_parity[i+5]   = L_d3;

/* symbol 4 */
d0   = data_d[i+7];
d1   = Enc1[i+7];
   d2   = Enc2[i+7];
   d3   = Enc2[i+6];
   tx = 2*d1 - 2*d2 + 4*d1*d2 - 1.0 + (((2*d1-1)*(2*d2-1))<0?(d3-0.5):(0.5-d3));
   tx = (d0 == 0 ? (tx - 4): (4 - tx));
rx   = tx + SIGMA_824_256QAM * gasdev();
   L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
               exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
               exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
               exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
              (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
               exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
               exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
               exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

   L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
               exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
               exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
               exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
              (exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
               exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
               exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
               exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

   L_d2 = log((exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+6.5)*(rx+6.5)) +
               exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
               exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
               exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
              (exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+4.5)*(rx+4.5)) +
               exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
               exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
               exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5))));

   L_d3 = log((exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+6.5)*(rx+6.5)) +
               exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+2.5)*(rx+2.5)) +
               exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-1.5)*(rx-1.5)) +
               exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-5.5)*(rx-5.5)))/
              (exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+4.5)*(rx+4.5)) +
               exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
               exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5)) +
               exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-7.5)*(rx-7.5))));
D1_data[i+7]   = L_d0;
D1_parity[i+7]   = L_d1;
   D2_parity[i+7] = L_d2;
   D2_parity[i+6] = L_d3;
```

```
        i = i+7;
      }
    /*
     * interleave data:
     */
    r_ileav(D1_data, rule);
#endif

/*mio*/

#ifdef R69_512QAM
    /*
     * Interleaver should be a multiple of 3, e.g., 6144
     *
     * Q dimension:
     * d0 is MSB and d4 is LSB in 32AM:(d0,d1,d2,d3,d4):
     *       00010--00011--00001--00000--00100--00101--00111--00110
     *       -15.5  -14.5  -13.5  -12.5  -11.5  -10.5  -9.5   -8.5
     *
     *       01010--01011--01001--01000--01100--01101--01111--01110
     *       -0.5   -1.5   -2.5   -3.5   -4.5   -5.5   -6.5   -7.5
     *
     *       11010--11011--11001--11000--11100--11101--11111--11110
     *       0.5    1.5    2.5    3.5    4.5    5.5    6.5    7.5
     *
     *       10010--10011--10001--10000--10100--10101--10111--10110
     *       15.5   14.5   13.5   12.5   11.5   10.5   9.5    8.5
     *
     * I dimension:
     * d0 is MSB and d3 is LSB in 16AM:(d0,d1,d2,d3):
     *
     *       0010---0011---0001---0000---0100---0101---0111---0110
     *       -7.5   -6.5   -5.5   -4.5   -3.5   -2.5   -1.5   -0.5
     *
     *       1010---1011---1001---1000---1100---1101---1111---1110
     *        7.5    6.5    5.5    4.5    3.5    2.5    1.5    0.5
     */

    /*
     * deinterleave data:
     */
    for(i = 0; i < INT_SIZE; i++)
      data_d[i] = data[i];
    r_deileava(data_d, rule);

    for(i = 0; i < INT_SIZE; i++)
      {
    /* symbol 1, Q dimension: 32AM */
    d0  = data_d[i];
    d1  = data_d[i+1];
        d2  = Enc1[i];
        d3  = Enc2[i];
        d4  = Enc1[i+1];
        tx  = 2*d2 - 2*d3 + 4*d2*d3 - 1.0 + (((2*d2-1)*(2*d3-1))<0?(d4-0.5):(0.5-d4));
        tx = (d1 == 0 ? (tx - 4): (4 - tx));
        tx = (d0 == 0 ? (tx - 8): (8 - tx));
    rx  = tx + SIGMA_32AM_of_39_512QAM * gasdev();
        n   = (-1.0) / (2 * SIGMA_32AM_of_39_512QAM * SIGMA_32AM_of_39_512QAM);
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                    exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                    exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                    exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
                    exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
                    exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-11.5)*(rx-11.5)) +
                    exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
                    exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5)))/
                   (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                    exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
                    exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                    exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)) +
                    exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
```

```
            exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
            exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
            exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5))));

L_d1 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
            exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)))/
           (exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
            exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-11.5)*(rx-11.5)) +
            exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5)) +
            exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
            exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
            exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
            exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5))));

L_d2 = log((exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)) +
            exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
            exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
            exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
            exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-11.5)*(rx-11.5)))/
           (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
            exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5))));

L_d3 = log((exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)) +
            exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
            exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
            exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5)))/
           (exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
            exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
            exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-10.5)*(rx-10.5))));

L_d4 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+9.5)*(rx+9.5)) +
            exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+13.5)*(rx+13.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-9.5)*(rx-9.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-13.5)*(rx-13.5)))/
           (exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+8.5)*(rx+8.5)) +
            exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+11.5)*(rx+11.5)) +
            exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+15.5)*(rx+15.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-7.5)*(rx-7.5))+exp(n*(rx-8.5)*(rx-8.5)) +
            exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-11.5)*(rx-11.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-15.5)*(rx-15.5))));
```

```
    D1_data[i]     = L_d0;
    D1_data[i+1]   = L_d1;
       D1_parity[i]   = L_d2;
       D2_parity[i]   = L_d3;
       D1_parity[i+1] = L_d4;

        /* symbol 1, I dimension: 16AM */
    d0 = data_d[i+2];
    d1 = Enc1[i+2];
    d2 = Enc2[i+2];
       d3 = Enc2[i+1];
       tx = 2*d1 - 2*d2 + 4*d1*d2 - 1.0 + (((2*d1-1)*(2*d2-1))<0?(d3-0.5):(0.5-d3));
       tx = (d0 == 0 ? (tx - 4): (4 - tx));
    rx = tx + SIGMA_16AM_of_39_512QAM * gasdev();
       n  = (-1.0) / (2 * SIGMA_16AM_of_39_512QAM * SIGMA_16AM_of_39_512QAM);
       L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                   exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                   exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                   exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
                  (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                   exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
                   exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                   exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

       L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                   exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                   exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                   exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                  (exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                   exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
                   exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                   exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

       L_d2 = log((exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+6.5)*(rx+6.5)) +
                   exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                   exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                   exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
                  (exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+4.5)*(rx+4.5)) +
                   exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                   exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                   exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5))));

       L_d3 = log((exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+6.5)*(rx+6.5)) +
                   exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                   exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                   exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-5.5)*(rx-5.5)))/
                  (exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+4.5)*(rx+4.5)) +
                   exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                   exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                   exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-7.5)*(rx-7.5))));

    D1_data[i+2]   = L_d0;
    D1_parity[i+2] = L_d1;
       D2_parity[i+2] = L_d2;
       D2_parity[i+1] = L_d3;
       i = i+2;
     }
    /*
     * interleave data:
     */
    r_ileav(D1_data, rule);

#endif


/*mio*/
#ifdef R12_16QAM
    /*
     * Channel:  we transmit two 4-AM symbols to emulate a 16-QAM symbol.
```

```
     * 2 info bits and 2 parity bits are mapped to 1 16-QAM symbols which in
     * turn are simulated as 2 4-AM symbols to achieve 2bit/s/Hz
     * d0 is MSB and d1 is LSB in a 4-AM:(d0,d1) = 01--00-|-10--11
     *                                             -3  -1    1   3
     * INT_SIZE to be a multiple of 2
     */

    n   = (-1.0) / (2 * SIGMA_12_16QAM * SIGMA_12_16QAM);
    for(i = 0; i < INT_SIZE; i++)
      {
        /* symbol 1 */
        d0  = data[i];
        d1  = Enc1[i];
        tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0;
        rx   = tx + SIGMA_12_16QAM * gasdev();
        L_d0 = log((exp(n*(rx-1)*(rx-1))+exp(n*(rx-3)*(rx-3))) /
                   (exp(n*(rx+1)*(rx+1))+exp(n*(rx+3)*(rx+3))));
        L_d1 = log((exp(n*(rx+3)*(rx+3))+exp(n*(rx-3)*(rx-3))) /
                   (exp(n*(rx-1)*(rx-1))+exp(n*(rx+1)*(rx+1))));
        D1_data[i]   = L_d0;
        D1_parity[i] = L_d1;
        D2_parity[i] = 0.0;

        /* symbol 2 */
        d0   = data[i+1];
        d1   = Enc2[i+1];
        tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0;
        rx   = tx + SIGMA_12_16QAM * gasdev();
        L_d0 = log((exp(n*(rx-1)*(rx-1))+exp(n*(rx-3)*(rx-3))) /
                   (exp(n*(rx+1)*(rx+1))+exp(n*(rx+3)*(rx+3))));
        L_d1 = log((exp(n*(rx+3)*(rx+3))+exp(n*(rx-3)*(rx-3))) /
                   (exp(n*(rx-1)*(rx-1))+exp(n*(rx+1)*(rx+1))));
        D1_data[i+1]   = L_d0;
        D2_parity[i+1] = L_d1;
        D1_parity[i+1] = 0.0;

        i = i+1;
      }
#endif

#ifdef R34_16QAM
    /*
     * Channel:  we transmit two 4-AM symbols to emulate a 16-QAM symbol.
     * 6 info bits and 2 parity bits are mapped to 2 16-QAM symbols which in
     * turn are simulated as 4 4-AM symbols to achieve 3bit/s/Hz
     * d0 is MSB and d1 is LSB in a 4-AM:(d0,d1) = 01--00-|-10--11
     *                                             -3  -1    1   3
     * INT_SIZE to be a multiple of 6
     */

    n   = (-1.0) / (2 * SIGMA_34_16QAM * SIGMA_34_16QAM);
    for(i = 0; i < INT_SIZE; i++)
      {
        /* symbol 1 */
        d0  = data[i];
        d1  = data[i+1];
        tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0;
        rx   = tx + SIGMA_34_16QAM * gasdev();
        L_d0 = log((exp(n*(rx-1)*(rx-1))+exp(n*(rx-3)*(rx-3))) /
                   (exp(n*(rx+1)*(rx+1))+exp(n*(rx+3)*(rx+3))));
        L_d1 = log((exp(n*(rx+3)*(rx+3))+exp(n*(rx-3)*(rx-3))) /
                   (exp(n*(rx-1)*(rx-1))+exp(n*(rx+1)*(rx+1))));
        D1_data[i]   = L_d0;
        D1_data[i+1] = L_d1;

        /* symbol 2 */
        d0   = data[i+2];
        d1   = Enc1[i+1];
        tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0;
        rx   = tx + SIGMA_34_16QAM * gasdev();
        L_d0 = log((exp(n*(rx-1)*(rx-1))+exp(n*(rx-3)*(rx-3))) /
```

```
                (exp(n*(rx+1)*(rx+1))+exp(n*(rx+3)*(rx+3))));
        L_d1 = log((exp(n*(rx+3)*(rx+3))+exp(n*(rx-3)*(rx-3))) /
                (exp(n*(rx-1)*(rx-1))+exp(n*(rx+1)*(rx+1))));
        D1_data[i+2] = L_d0;
        D1_parity[i+1] = L_d1;

        /* symbol 3 */
        d0   = data[i+3];
        d1   = data[i+4];
        tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0;
        rx   = tx + SIGMA_34_16QAM * gasdev();
        L_d0 = log((exp(n*(rx-1)*(rx-1))+exp(n*(rx-3)*(rx-3))) /
                (exp(n*(rx+1)*(rx+1))+exp(n*(rx+3)*(rx+3))));
        L_d1 = log((exp(n*(rx+3)*(rx+3))+exp(n*(rx-3)*(rx-3))) /
                (exp(n*(rx-1)*(rx-1))+exp(n*(rx+1)*(rx+1))));
        D1_data[i+3] = L_d0;
        D1_data[i+4] = L_d1;

        /* symbol 4 */
        d0   = data[i+5];
        d1   = Enc2[i+4];
        tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0;
        rx   = tx + SIGMA_34_16QAM * gasdev();
        L_d0 = log((exp(n*(rx-1)*(rx-1))+exp(n*(rx-3)*(rx-3))) /
                (exp(n*(rx+1)*(rx+1))+exp(n*(rx+3)*(rx+3))));
        L_d1 = log((exp(n*(rx+3)*(rx+3))+exp(n*(rx-3)*(rx-3))) /
                (exp(n*(rx-1)*(rx-1))+exp(n*(rx+1)*(rx+1))));
        D1_data[i+5]   = L_d0;
        D2_parity[i+4] = L_d1;
        D1_parity[i]   = 0.0;
        D1_parity[i+2] = 0.0;
        D1_parity[i+3] = 0.0;
        D1_parity[i+4] = 0.0;
        D1_parity[i+5] = 0.0;
        D2_parity[i]   = 0.0;
        D2_parity[i+1] = 0.0;
        D2_parity[i+2] = 0.0;
        D2_parity[i+3] = 0.0;
        D2_parity[i+5] = 0.0;
        i = i+5;
      }
#endif

#ifdef R56_64QAM
    /*
     * Channel:
     * d0 is MSB and d2 is LSB in 8AM:(d0,d1,d2):
     *       010---011---001---000---100---101---111---110
     *      -3.5  -2.5  -1.5  -0.5   0.5   1.5   2.5   3.5
     */
    /*
     * Channel:  we transmit two 8AM symbols to emulate a 64QAM symbol.
     * 10 info bits and 2 parity bits are mapped to 2 64QAM symbols which in
     * turn are simulated as 4 8AM symbols to achieve 5bit/s/Hz.
     *
     * INT_SIZE to be a multiple of 10
     */
    n   = (-1.0) / (2 * SIGMA_56_64QAM * SIGMA_56_64QAM);
    for(i = 0; i < INT_SIZE; i++)
      {
        /* symbol 1 */
        d0  = data[i];
        d1  = data[i+1];
        d2  = Enc1[i];
        tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0 + (((2*d0-1)*(2*d1-1))<0?(d2-0.5):(0.5-d2));
        rx   = tx + SIGMA_56_64QAM * gasdev();
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                    exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                   (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                    exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));
```

```
L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
           exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
          (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
           exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

L_d2 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
           exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
          (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
           exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));
D1_data[i]     = L_d0;
D1_data[i+1]   = L_d1;
D1_parity[i]   = L_d2;
D1_parity[i+1] = 0;
D2_parity[i]   = 0;
D2_parity[i+1] = 0;

/* symbol 2 */
d0   = data[i+2];
d1   = data[i+3];
d2   = data[i+4];
tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0 + (((2*d0-1)*(2*d1-1))<0?(d2-0.5):(0.5-d2));
rx   = tx + SIGMA_56_64QAM * gasdev();
L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
           exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
          (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
           exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));

L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
           exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
          (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
           exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

L_d2 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
           exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
          (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
           exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));
D1_data[i+2]   = L_d0;
D1_data[i+3]   = L_d1;
D1_data[i+4]   = L_d2;
D1_parity[i+2] = 0;
D1_parity[i+3] = 0;
D1_parity[i+4] = 0;
D2_parity[i+2] = 0;
D2_parity[i+3] = 0;
D2_parity[i+4] = 0;

/* symbol 3 */
d0   = data[i+5];
d1   = data[i+6];
d2   = Enc2[i+5];
tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0 + (((2*d0-1)*(2*d1-1))<0?(d2-0.5):(0.5-d2));
rx   = tx + SIGMA_56_64QAM * gasdev();
L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
           exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
          (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
           exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));

L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
           exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
          (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
           exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

L_d2 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
           exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
          (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
           exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));
D1_data[i+5]   = L_d0;
D1_data[i+6]   = L_d1;
D2_parity[i+5] = L_d2;
D2_parity[i+6] = 0;
D1_parity[i+5] = 0;
```

```
        D1_parity[i+6] = 0;

        /* symbol 4 */
        d0   = data[i+7];
        d1   = data[i+8];
        d2   = data[i+9];
        tx   = 2*d0 - 2*d1 + 4*d0*d1 - 1.0 + (((2*d0-1)*(2*d1-1))<0?(d2-0.5):(0.5-d2));
        rx   = tx + SIGMA_56_64QAM * gasdev();
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                   exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                  (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                   exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));

        L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                   exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                  (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                   exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

        L_d2 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                   exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
                  (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                   exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));
        D1_data[i+7]   = L_d0;
        D1_data[i+8]   = L_d1;
        D1_data[i+9]   = L_d2;
        D1_parity[i+7] = 0;
        D1_parity[i+8] = 0;
        D1_parity[i+9] = 0;
        D2_parity[i+7] = 0;
        D2_parity[i+8] = 0;
        D2_parity[i+9] = 0;

        i = i+9;
      }
#endif


#ifdef R57_128QAM
    /*
     * Q dimension:
     * d0 is MSB and d2 is LSB in 8-AM:(d0,d1,d2):
     *       010---011---001---000---100---101---111---110
     *      -3.5  -2.5  -1.5  -0.5   0.5   1.5   2.5   3.5
     * I dimension:
     * d0 is MSB and d3 is LSB in 16AM:(d0,d1,d2,d3):
     *
     *       0010---0011---0001---0000---0100---0101---0111---0110
     *       -7.5   -6.5   -5.5   -4.5   -3.5   -2.5   -1.5   -0.5
     *
     *       1010---1011---1001---1000---1100---1101---1111---1110
     *        7.5    6.5    5.5    4.5    3.5    2.5    1.5    0.5
     *
     * INT_SIZE to be a multiple of 5
     */

    for(i = 0; i < INT_SIZE; i++)
      {
        /* Q dimension: 8AM */
        d0  = data[i];
        d1  = data[i+1];
        d2  = Enc1[i];
        tx  = 2*d0 - 2*d1 + 4*d0*d1 - 1.0 + (((2*d0-1)*(2*d1-1))<0?(d2-0.5):(0.5-d2));
        rx  = tx + SIGMA_8AM_of_128QAM * gasdev();
        n   = (-1.0) / (2 * SIGMA_8AM_of_128QAM * SIGMA_8AM_of_128QAM);
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                   exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                  (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                   exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5))));

        L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                   exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
```

```
                (exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                 exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5))));

    L_d2 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                exp(n*(rx-1.5)*(rx-1.5))+exp(n*(rx-2.5)*(rx-2.5)))/
               (exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5))));
    D1_data[i]     = L_d0;
    D1_data[i+1]   = L_d1;
    D1_parity[i]   = L_d2;
    D1_parity[i+1] = 0.0;
    D1_parity[i+2] = 0.0;
    D1_parity[i+3] = 0.0;
    D1_parity[i+4] = 0.0;

    /* I dimension: 16AM */
    d0 = data[i+2];
    d1 = data[i+3];
    d2 = data[i+4];
    d3 = Enc2[i];
    tx = 2*d1 - 2*d2 + 4*d1*d2 - 1.0 + (((2*d1-1)*(2*d2-1))<0?(d3-0.5):(0.5-d3));
    tx = (d0 == 0 ? (tx - 4): (4 - tx));
    rx = tx + SIGMA_16AM_of_128QAM * gasdev();
    n  = (-1.0) / (2 * SIGMA_16AM_of_128QAM * SIGMA_16AM_of_128QAM);
    L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
               (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
                exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

    L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
               (exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
                exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

    L_d2 = log((exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+6.5)*(rx+6.5)) +
                exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
               (exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+4.5)*(rx+4.5)) +
                exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5))));

    L_d3 = log((exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+6.5)*(rx+6.5)) +
                exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-5.5)*(rx-5.5)))/
               (exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+4.5)*(rx+4.5)) +
                exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-7.5)*(rx-7.5))));

    D1_data[i+2]   = L_d0;
    D1_data[i+3]   = L_d1;
    D1_data[i+4]   = L_d2;
    D2_parity[i]   = L_d3;
    D2_parity[i+1] = 0.0;
    D2_parity[i+2] = 0.0;
    D2_parity[i+3] = 0.0;
    D2_parity[i+4] = 0.0;

    i = i+4;
}
```

```
#endif


#ifdef R58_256QAM
    /*
     * Channel:
     * d0 is MSB and d3 is LSB in 16AM:(d0,d1,d2,d3):
     *
     *       0010---0011---0001---0000---0100---0101---0111---0110
     *       -7.5   -6.5   -5.5   -4.5   -3.5   -2.5   -1.5   -0.5
     *
     *       1010---1011---1001---1000---1100---1101---1111---1110
     *        7.5    6.5    5.5    4.5    3.5    2.5    1.5    0.5
     *
     * Channel:  we transmit two 16AM symbols to emulate a 256QAM symbol.
     * 10 info bits and 6 parity bits are mapped to 2 256QAM symbols which in
     * turn are simulated as 4 16AM symbols to achieve 6bit/s/Hz.
     *
     * INT_SIZE to be a multiple of 10
     */

    n   = (-1.0) / (2 * SIGMA_58_256QAM * SIGMA_58_256QAM);

    /*
     * deinterleave data:
     */
    for(i = 0; i < INT_SIZE; i++)
      data_d[i] = data[i];
    r_deileava(data_d, rule);

    for(i = 0; i < INT_SIZE; i++)
      {
        /* symbol 1 */
        d0 = data_d[i];
        d1 = data_d[i+1];
        d2 = data_d[i+2];
       d3 = Enc1[i];
       tx = 2*d1 - 2*d2 + 4*d1*d2 - 1.0 + (((2*d1-1)*(2*d2-1))<0?(d3-0.5):(0.5-d3));
       tx = (d0 == 0 ? (tx - 4): (4 - tx));
       /* Test the mapping to the 16AM constellation:
        * if (i < 500)
        *  printf("\n(%d%d%d%d) = %f", (int)d0, (int)d1, (int)d2, (int)d3, tx);
        */
        rx   = tx + SIGMA_58_256QAM * gasdev();
       L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                   exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                   exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                   exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
                  (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                   exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
                   exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                   exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

       L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                   exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                   exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                   exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                  (exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                   exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
                   exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                   exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

       L_d2 = log((exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+6.5)*(rx+6.5)) +
                   exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                   exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                   exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
                  (exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+4.5)*(rx+4.5)) +
                   exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                   exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                   exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5))));
```

```
L_d3 = log((exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+6.5)*(rx+6.5)) +
           exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+2.5)*(rx+2.5)) +
           exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-1.5)*(rx-1.5)) +
           exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-5.5)*(rx-5.5)))/
          (exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+4.5)*(rx+4.5)) +
           exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
           exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5)) +
           exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-7.5)*(rx-7.5))));

 D1_data[i]     = L_d0;
 D1_data[i+1]   = L_d1;
D1_data[i+2]   = L_d2;
D1_parity[i]   = L_d3;
D1_parity[i+1] = 0;
D1_parity[i+2] = 0;
D2_parity[i]   = 0;
D2_parity[i+1] = 0;

 /* symbol 2 */
 d0 = data_d[i+3];
 d1 = data_d[i+4];
d2 = Enc2[i+2];
d3 = Enc1[i+4];
tx = 2*d1 - 2*d2 + 4*d1*d2 - 1.0 + (((2*d1-1)*(2*d2-1))<0?(d3-0.5):(0.5-d3));
tx = (d0 == 0 ? (tx - 4): (4 - tx));
 rx   = tx + SIGMA_58_256QAM * gasdev();
L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
           exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
           exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
           exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
          (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
           exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
           exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
           exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
           exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
           exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
           exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
          (exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
           exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
           exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
           exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

L_d2 = log((exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+6.5)*(rx+6.5)) +
           exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
           exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
           exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
          (exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+4.5)*(rx+4.5)) +
           exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
           exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
           exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5))));

L_d3 = log((exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+6.5)*(rx+6.5)) +
           exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+2.5)*(rx+2.5)) +
           exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-1.5)*(rx-1.5)) +
           exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-5.5)*(rx-5.5)))/
          (exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+4.5)*(rx+4.5)) +
           exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
           exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5)) +
           exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-7.5)*(rx-7.5))));
 D1_data[i+3]   = L_d0;
 D1_data[i+4]   = L_d1;
 D2_parity[i+2] = L_d2;
 D1_parity[i+4] = L_d3;
D1_parity[i+3] = 0;
D2_parity[i+3] = 0;
D2_parity[i+4] = 0;

 /* symbol 3 */
 d0   = data_d[i+5];
```

```
 d1    = data_d[i+6];
 d2    = data_d[i+7];
d3    = Enc2[i+5];
tx = 2*d1 - 2*d2 + 4*d1*d2 - 1.0 + (((2*d1-1)*(2*d2-1))<0?(d3-0.5):(0.5-d3));
tx = (d0 == 0 ? (tx - 4): (4 - tx));
 rx    = tx + SIGMA_58_256QAM * gasdev();
L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
           (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
            exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
           (exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
            exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

L_d2 = log((exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+6.5)*(rx+6.5)) +
            exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
           (exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+4.5)*(rx+4.5)) +
            exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5))));

L_d3 = log((exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+6.5)*(rx+6.5)) +
            exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+2.5)*(rx+2.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-5.5)*(rx-5.5)))/
           (exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+4.5)*(rx+4.5)) +
            exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-7.5)*(rx-7.5))));
 D1_data[i+5]    = L_d0;
 D1_data[i+6]    = L_d1;
 D1_data[i+7]    = L_d2;
D2_parity[i+5] = L_d3;
D2_parity[i+6] = 0;
D2_parity[i+7] = 0;
D1_parity[i+5] = 0;
D1_parity[i+6] = 0;

 /* symbol 4 */
 d0    = data_d[i+8];
 d1    = data_d[i+9];
d2    = Enc1[i+7];
d3    = Enc2[i+9];
tx = 2*d1 - 2*d2 + 4*d1*d2 - 1.0 + (((2*d1-1)*(2*d2-1))<0?(d3-0.5):(0.5-d3));
tx = (d0 == 0 ? (tx - 4): (4 - tx));
 rx    = tx + SIGMA_58_256QAM * gasdev();
L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
           (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
            exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
```

```
                    (exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                     exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
                     exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                     exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

          L_d2 = log((exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+6.5)*(rx+6.5)) +
                     exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                     exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                     exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
                    (exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+4.5)*(rx+4.5)) +
                     exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                     exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                     exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5))));

          L_d3 = log((exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+6.5)*(rx+6.5)) +
                     exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                     exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                     exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-5.5)*(rx-5.5)))/
                    (exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+4.5)*(rx+4.5)) +
                     exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                     exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                     exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-7.5)*(rx-7.5))));
          D1_data[i+8]    = L_d0;
          D1_data[i+9]    = L_d1;
          D1_parity[i+7] = L_d2;
          D2_parity[i+9] = L_d3;
          D1_parity[i+8] = 0;
          D1_parity[i+9] = 0;
          D2_parity[i+7] = 0;
          D2_parity[i+8] = 0;

          i = i+9;
        }
      /*
       * interleave data:
       */
      r_ileav(D1_data, rule);
#endif


#ifdef R68_256QAM
      /*
       * Channel:
       * d0 is MSB and d3 is LSB in 16AM:(d0,d1,d2,d3):
       *
       *       0010---0011---0001---0000---0100---0101---0111---0110
       *       -7.5   -6.5   -5.5   -4.5   -3.5   -2.5   -1.5   -0.5
       *
       *       1010---1011---1001---1000---1100---1101---1111---1110
       *        7.5    6.5    5.5    4.5    3.5    2.5    1.5    0.5
       *
       * Channel:  we transmit two 16AM symbols to emulate a 256QAM symbol.
       * 6 info bits and 2 parity bits are mapped to one 256QAM symbol which in
       * turn is simulated as 2 16AM symbols to achieve 6bit/s/Hz.
       *
       * INT_SIZE to be a multiple of 6
       */
      n   = (-1.0) / (2 * SIGMA_68_256QAM * SIGMA_68_256QAM);

      /*
       * deinterleave data:
       */
      for(i = 0; i < INT_SIZE; i++)
        data_d[i] = data[i];
      r_deileava(data_d, rule);

      for(i = 0; i < INT_SIZE; i++)
        {
          /* symbol 1 */
          d0 = data_d[i];
          d1 = data_d[i+1];
```

```
d2 = data_d[i+2];
d3 = Enc1[i];
tx = 2*d1 - 2*d2 + 4*d1*d2 - 1.0 + (((2*d1-1)*(2*d2-1))<0?(d3-0.5):(0.5-d3));
tx = (d0 == 0 ? (tx - 4): (4 - tx));
rx   = tx + SIGMA_68_256QAM * gasdev();
L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
           (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
            exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
           (exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
            exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

L_d2 = log((exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+6.5)*(rx+6.5)) +
            exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
           (exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+4.5)*(rx+4.5)) +
            exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5))));

L_d3 = log((exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+6.5)*(rx+6.5)) +
            exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+2.5)*(rx+2.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-5.5)*(rx-5.5)))/
           (exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+4.5)*(rx+4.5)) +
            exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-7.5)*(rx-7.5))));

 D1_data[i]     = L_d0;
 D1_data[i+1]   = L_d1;
D1_data[i+2]   = L_d2;
D1_parity[i]   = L_d3;
D1_parity[i+1] = 0;
D1_parity[i+2] = 0;
D2_parity[i]   = 0;
D2_parity[i+1] = 0;
D2_parity[i+2] = 0;

 /* symbol 2 */
 d0 = data_d[i+3];
 d1 = data_d[i+4];
d2 = data_d[i+5];
d3 = Enc2[i+3];
tx = 2*d1 - 2*d2 + 4*d1*d2 - 1.0 + (((2*d1-1)*(2*d2-1))<0?(d3-0.5):(0.5-d3));
tx = (d0 == 0 ? (tx - 4): (4 - tx));
 rx   = tx + SIGMA_68_256QAM * gasdev();
L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
           (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
            exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
```

```
                    exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                   (exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                    exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
                    exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                    exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

          L_d2 = log((exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+6.5)*(rx+6.5)) +
                    exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                    exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                    exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
                   (exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+4.5)*(rx+4.5)) +
                    exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                    exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                    exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5))));

          L_d3 = log((exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+6.5)*(rx+6.5)) +
                    exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                    exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                    exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-5.5)*(rx-5.5)))/
                   (exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+4.5)*(rx+4.5)) +
                    exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                    exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                    exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-7.5)*(rx-7.5))));
          D1_data[i+3]   = L_d0;
          D1_data[i+4]   = L_d1;
          D1_data[i+5]   = L_d2;
          D2_parity[i+3] = L_d3;
          D2_parity[i+4] = 0;
          D2_parity[i+5] = 0;
          D1_parity[i+3] = 0;
          D1_parity[i+4] = 0;
          D1_parity[i+5] = 0;

          i = i+5;
        }

      /*
       * interleave data:
       */
      r_ileav(D1_data, rule);

#endif


#ifdef R69_512QAM
      /*
       * Interleaver should be a multiple of 12, e.g., 6144
       *
       * Q dimension:
       * d0 is MSB and d4 is LSB in 32AM:(d0,d1,d2,d3,d4):
       *       00010--00011--00001--00000--00100--00101--00111--00110
       *       -15.5  -14.5  -13.5  -12.5  -11.5  -10.5  -9.5   -8.5
       *
       *       01010--01011--01001--01000--01100--01101--01111--01110
       *       -0.5   -1.5   -2.5   -3.5   -4.5   -5.5   -6.5   -7.5
       *
       *       11010--11011--11001--11000--11100--11101--11111--11110
       *       0.5    1.5    2.5    3.5    4.5    5.5    6.5    7.5
       *
       *       10010--10011--10001--10000--10100--10101--10111--10110
       *       15.5   14.5   13.5   12.5   11.5   10.5   9.5    8.5
       *
       * I dimension:
       * d0 is MSB and d3 is LSB in 16AM:(d0,d1,d2,d3):
       *
       *       0010---0011---0001---0000---0100---0101---0111---0110
       *       -7.5   -6.5   -5.5   -4.5   -3.5   -2.5   -1.5   -0.5
       *
       *       1010---1011---1001---1000---1100---1101---1111---1110
       *        7.5    6.5    5.5    4.5    3.5    2.5    1.5    0.5
```

```
 */

/*
 * deinterleave data:
 */
for(i = 0; i < INT_SIZE; i++)
  data_d[i] = data[i];
r_deileava(data_d, rule);

for(i = 0; i < INT_SIZE; i++)
  {
    /* symbol 1, Q dimension: 32AM */
    d0  = data_d[i];
    d1  = data_d[i+1];
   d2  = data_d[i+2];
   d3  = data_d[i+3];
   d4  = Enc1[i];
   tx  = 2*d2 - 2*d3 + 4*d2*d3 - 1.0 + (((2*d2-1)*(2*d3-1))<0?(d4-0.5):(0.5-d4));
   tx = (d1 == 0 ? (tx - 4): (4 - tx));
   tx = (d0 == 0 ? (tx - 8): (8 - tx));
    rx  = tx + SIGMA_32AM_of_512QAM * gasdev();
   n   = (-1.0) / (2 * SIGMA_32AM_of_512QAM * SIGMA_32AM_of_512QAM);
   L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
               exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
               exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
               exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
               exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
               exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-11.5)*(rx-11.5)) +
               exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
               exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5)))/
              (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
               exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
               exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
               exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)) +
               exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
               exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
               exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
               exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5))));

   L_d1 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
               exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
               exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
               exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
               exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
               exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
               exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
               exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)))/
              (exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
               exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-11.5)*(rx-11.5)) +
               exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
               exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5)) +
               exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
               exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
               exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
               exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5))));

   L_d2 = log((exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
               exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)) +
               exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
               exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
               exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
               exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
               exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
               exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-11.5)*(rx-11.5)))/
              (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
               exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
               exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
               exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5)) +
               exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
               exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
               exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
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```
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5))));

L_d3 = log((exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)) +
            exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
            exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
            exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5)))/
           (exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
            exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
            exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-10.5)*(rx-10.5))));

L_d4 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+9.5)*(rx+9.5)) +
            exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+13.5)*(rx+13.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-9.5)*(rx-9.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-13.5)*(rx-13.5)))/
           (exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+8.5)*(rx+8.5)) +
            exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+11.5)*(rx+11.5)) +
            exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+15.5)*(rx+15.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-7.5)*(rx-7.5))+exp(n*(rx-8.5)*(rx-8.5)) +
            exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-11.5)*(rx-11.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-15.5)*(rx-15.5))));


 D1_data[i]     = L_d0;
 D1_data[i+1]   = L_d1;
D1_data[i+2]   = L_d2;
D1_data[i+3]   = L_d3;
D1_parity[i]   = L_d4;
D1_parity[i+1] = 0.0;
D1_parity[i+2] = 0.0;
D1_parity[i+3] = 0.0;
D1_parity[i+5] = 0.0;

 /* symbol 1, I dimension: 16AM */
 d0 = data_d[i+4];
 d1 = data_d[i+5];
 d2 = Enc1[i+4];
d3 = Enc2[i+2];
tx = 2*d1 - 2*d2 + 4*d1*d2 - 1.0 + (((2*d1-1)*(2*d2-1))<0?(d3-0.5):(0.5-d3));
tx = (d0 == 0 ? (tx - 4): (4 - tx));
 rx = tx + SIGMA_16AM_of_512QAM * gasdev();
n  = (-1.0) / (2 * SIGMA_16AM_of_512QAM * SIGMA_16AM_of_512QAM);
L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
           (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
            exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
           (exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
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            exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

L_d2 = log((exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+6.5)*(rx+6.5)) +
            exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
           (exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+4.5)*(rx+4.5)) +
            exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5))));

L_d3 = log((exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+6.5)*(rx+6.5)) +
            exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+2.5)*(rx+2.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-5.5)*(rx-5.5)))/
           (exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+4.5)*(rx+4.5)) +
            exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-7.5)*(rx-7.5))));

 D1_data[i+4]   = L_d0;
 D1_data[i+5]   = L_d1;
D1_parity[i+4] = L_d2;
D2_parity[i+2] = L_d3;
D2_parity[i]   = 0.0;
D2_parity[i+1] = 0.0;
D2_parity[i+3] = 0.0;
D2_parity[i+4] = 0.0;
D2_parity[i+5] = 0.0;

 /* symbol 2, Q dimension: 32AM */
 d0  = data_d[i+6];
 d1  = data_d[i+7];
d2  = data_d[i+8];
d3  = data_d[i+9];
d4  = Enc2[i+6];
tx  = 2*d2 - 2*d3 + 4*d2*d3 - 1.0 + (((2*d2-1)*(2*d3-1))<0?(d4-0.5):(0.5-d4));
tx = (d1 == 0 ? (tx - 4): (4 - tx));
tx = (d0 == 0 ? (tx - 8): (8 - tx));
 rx  = tx + SIGMA_32AM_of_512QAM * gasdev();
n   = (-1.0) / (2 * SIGMA_32AM_of_512QAM * SIGMA_32AM_of_512QAM);
L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
            exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
            exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-11.5)*(rx-11.5)) +
            exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5)))/
           (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)) +
            exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
            exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
            exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
            exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5))));

L_d1 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
            exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)))/
           (exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
            exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-11.5)*(rx-11.5)) +
            exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5)) +
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            exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
            exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
            exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
            exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5))));

L_d2 = log((exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)) +
            exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
            exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
            exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
            exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-11.5)*(rx-11.5)))/
           (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
            exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5))));

L_d3 = log((exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)) +
            exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
            exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
            exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5)))/
           (exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
            exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
            exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-10.5)*(rx-10.5))));

L_d4 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+9.5)*(rx+9.5)) +
            exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+13.5)*(rx+13.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-9.5)*(rx-9.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-13.5)*(rx-13.5)))/
           (exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+8.5)*(rx+8.5)) +
            exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+11.5)*(rx+11.5)) +
            exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+15.5)*(rx+15.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-7.5)*(rx-7.5))+exp(n*(rx-8.5)*(rx-8.5)) +
            exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-11.5)*(rx-11.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-15.5)*(rx-15.5))));


 D1_data[i+6]   = L_d0;
 D1_data[i+7]   = L_d1;
D1_data[i+8]   = L_d2;
D1_data[i+9]   = L_d3;
D2_parity[i+6] = L_d4;
D2_parity[i+7] = 0.0;
D2_parity[i+8] = 0.0;
D2_parity[i+9] = 0.0;
D2_parity[i+11] = 0.0;

 /* symbol 2, I dimension: 16AM */
 d0 = data_d[i+10];
 d1 = data_d[i+11];
 d2 = Enc2[i+10];
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        d3 = Enc1[i+8];
        tx = 2*d1 - 2*d2 + 4*d1*d2 - 1.0 + (((2*d1-1)*(2*d2-1))<0?(d3-0.5):(0.5-d3));
        tx = (d0 == 0 ? (tx - 4): (4 - tx));
        rx = tx + SIGMA_16AM_of_512QAM * gasdev();
        n  = (-1.0) / (2 * SIGMA_16AM_of_512QAM * SIGMA_16AM_of_512QAM);
        L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                    exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                    exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                    exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
                   (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                    exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
                    exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                    exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

        L_d1 = log((exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                    exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                    exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                    exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)))/
                   (exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                    exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
                    exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                    exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5))));

        L_d2 = log((exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+6.5)*(rx+6.5)) +
                    exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                    exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                    exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)))/
                   (exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+4.5)*(rx+4.5)) +
                    exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                    exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                    exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5))));

        L_d3 = log((exp(n*(rx+5.5)*(rx+5.5))+exp(n*(rx+6.5)*(rx+6.5)) +
                    exp(n*(rx+1.5)*(rx+1.5))+exp(n*(rx+2.5)*(rx+2.5)) +
                    exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                    exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-5.5)*(rx-5.5)))/
                   (exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+4.5)*(rx+4.5)) +
                    exp(n*(rx+3.5)*(rx+3.5))+exp(n*(rx+0.5)*(rx+0.5)) +
                    exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                    exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-7.5)*(rx-7.5))));

        D1_data[i+10]    = L_d0;
        D1_data[i+11]    = L_d1;
        D2_parity[i+10] = L_d2;
        D1_parity[i+8]   = L_d3;
        D1_parity[i+6]   = 0.0;
        D1_parity[i+7]   = 0.0;
        D1_parity[i+9]   = 0.0;
        D1_parity[i+10] = 0.0;
        D1_parity[i+11] = 0.0;

        i = i+11;
      }
    /*
     * interleave data:
     */
    r_ileav(D1_data, rule);

#endif


#ifdef R710_1024QAM
    /*
     * Use S2044_33_1 interleaver (multiple of 14)
     *
     * I and Q dimensions:
     * d0 is MSB and d4 is LSB in 32AM:(d0,d1,d2,d3,d4):
     *       00010--00011--00001--00000--00100--00101--00111--00110
     *       -15.5  -14.5  -13.5  -12.5  -11.5  -10.5  -9.5   -8.5
     *
     *       01010--01011--01001--01000--01100--01101--01111--01110
```

```
 *       -0.5   -1.5   -2.5   -3.5   -4.5   -5.5   -6.5   -7.5
 *
 *       11010--11011--11001--11000--11100--11101--11111--11110
 *       0.5    1.5    2.5    3.5    4.5    5.5    6.5    7.5
 *
 *       10010--10011--10001--10000--10100--10101--10111--10110
 *       15.5   14.5   13.5   12.5   11.5   10.5   9.5    8.5
 *
 */

n   = (-1.0) / (2 * SIGMA_710_1024QAM * SIGMA_710_1024QAM);
for(i = 0; i < INT_SIZE; i++)
  {
    /* symbol 1, Q dimension */
    d0  = data[i];
    d1  = data[i+1];
    d2  = data[i+2];
    d3  = data[i+3];
    d4  = Enc1[i];
    tx  = 2*d2 - 2*d3 + 4*d2*d3 - 1.0 + (((2*d2-1)*(2*d3-1))<0?(d4-0.5):(0.5-d4));
    tx = (d1 == 0 ? (tx - 4): (4 - tx));
    tx = (d0 == 0 ? (tx - 8): (8 - tx));
    rx  = tx + SIGMA_710_1024QAM * gasdev();
    L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
                exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
                exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-11.5)*(rx-11.5)) +
                exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
                exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5)))/
               (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
                exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)) +
                exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
                exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
                exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
                exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5))));

    L_d1 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
                exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
                exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
                exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)))/
               (exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
                exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-11.5)*(rx-11.5)) +
                exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
                exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5)) +
                exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
                exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
                exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
                exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5))));

    L_d2 = log((exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
                exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)) +
                exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
                exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
                exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
                exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
                exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
                exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-11.5)*(rx-11.5)))/
               (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
                exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
                exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
                exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5)) +
                exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
                exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
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```
            exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5))));

L_d3 = log((exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)) +
            exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
            exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
            exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5)))/
           (exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
            exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
            exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-10.5)*(rx-10.5))));

L_d4 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+9.5)*(rx+9.5)) +
            exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+13.5)*(rx+13.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-9.5)*(rx-9.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-13.5)*(rx-13.5)))/
           (exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+8.5)*(rx+8.5)) +
            exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+11.5)*(rx+11.5)) +
            exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+15.5)*(rx+15.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-7.5)*(rx-7.5))+exp(n*(rx-8.5)*(rx-8.5)) +
            exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-11.5)*(rx-11.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-15.5)*(rx-15.5))));


 D1_data[i]     = L_d0;
 D1_data[i+1]   = L_d1;
D1_data[i+2]   = L_d2;
D1_data[i+3]   = L_d3;
D1_parity[i]   = L_d4;
D1_parity[i+1] = 0.0;
D1_parity[i+2] = 0.0;
D1_parity[i+3] = 0.0;
D1_parity[i+4] = 0.0;
D1_parity[i+6] = 0.0;

 /* symbol 1, I dimension */
 d0 = data[i+4];
 d1 = data[i+5];
 d2 = data[i+6];
d3 = Enc1[i+5];
d4 = Enc2[i];
tx  = 2*d2 - 2*d3 + 4*d2*d3 - 1.0 + (((2*d2-1)*(2*d3-1))<0?(d4-0.5):(0.5-d4));
tx = (d1 == 0 ? (tx - 4): (4 - tx));
tx = (d0 == 0 ? (tx - 8): (8 - tx));
 rx  = tx + SIGMA_710_1024QAM * gasdev();
L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
            exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
            exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-11.5)*(rx-11.5)) +
            exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5)))/
           (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)) +
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            exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
            exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
            exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
            exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5))));

L_d1 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
            exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)))/
           (exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
            exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-11.5)*(rx-11.5)) +
            exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5)) +
            exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
            exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
            exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
            exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5))));

L_d2 = log((exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)) +
            exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
            exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
            exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
            exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-11.5)*(rx-11.5)))/
           (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
            exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5))));

L_d3 = log((exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)) +
            exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
            exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
            exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5)))/
           (exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
            exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
            exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-10.5)*(rx-10.5))));

L_d4 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+9.5)*(rx+9.5)) +
            exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+13.5)*(rx+13.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-9.5)*(rx-9.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-13.5)*(rx-13.5)))/
           (exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+8.5)*(rx+8.5)) +
            exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+11.5)*(rx+11.5)) +
            exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+15.5)*(rx+15.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-7.5)*(rx-7.5))+exp(n*(rx-8.5)*(rx-8.5)) +
            exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-11.5)*(rx-11.5)) +
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            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-15.5)*(rx-15.5))));

D1_data[i+4]   = L_d0;
D1_data[i+5]   = L_d1;
D1_data[i+6]   = L_d2;
D1_parity[i+5] = L_d3;
D2_parity[i]   = L_d4;
D2_parity[i+1] = 0.0;
D2_parity[i+2] = 0.0;
D2_parity[i+3] = 0.0;
D2_parity[i+4] = 0.0;
D2_parity[i+6] = 0.0;

/* symbol 2, Q dimension */
d0  = data[i+7];
d1  = data[i+8];
d2  = data[i+9];
d3  = data[i+10];
d4  = Enc2[i+5];
tx  = 2*d2 - 2*d3 + 4*d2*d3 - 1.0 + (((2*d2-1)*(2*d3-1))<0?(d4-0.5):(0.5-d4));
tx = (d1 == 0 ? (tx - 4): (4 - tx));
tx = (d0 == 0 ? (tx - 8): (8 - tx));
rx  = tx + SIGMA_710_1024QAM * gasdev();
L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
           exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
           exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
           exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
           exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
           exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-11.5)*(rx-11.5)) +
           exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
           exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5)))/
          (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
           exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
           exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
           exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)) +
           exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
           exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
           exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
           exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5))));

L_d1 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
           exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
           exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
           exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
           exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
           exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
           exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
           exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)))/
          (exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
           exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-11.5)*(rx-11.5)) +
           exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
           exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5)) +
           exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
           exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
           exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
           exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5))));

L_d2 = log((exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
           exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)) +
           exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
           exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
           exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
           exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
           exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
           exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-11.5)*(rx-11.5)))/
          (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
           exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
           exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
           exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5)) +
           exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
           exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
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            exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5))));

L_d3 = log((exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)) +
            exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
            exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
            exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5)))/
           (exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
            exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
            exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-10.5)*(rx-10.5))));

L_d4 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+9.5)*(rx+9.5)) +
            exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+13.5)*(rx+13.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-9.5)*(rx-9.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-13.5)*(rx-13.5)))/
           (exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+8.5)*(rx+8.5)) +
            exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+11.5)*(rx+11.5)) +
            exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+15.5)*(rx+15.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-7.5)*(rx-7.5))+exp(n*(rx-8.5)*(rx-8.5)) +
            exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-11.5)*(rx-11.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-15.5)*(rx-15.5))));


 D1_data[i+7]   = L_d0;
 D1_data[i+8]   = L_d1;
D1_data[i+9]   = L_d2;
D1_data[i+10]  = L_d3;
D2_parity[i+5] = L_d4;
D2_parity[i+7] = 0.0;
D2_parity[i+8] = 0.0;
D2_parity[i+9] = 0.0;
D2_parity[i+11] = 0.0;
D2_parity[i+12] = 0.0;
D2_parity[i+13] = 0.0;

 /* symbol 2, I dimension */
 d0 = data[i+11];
 d1 = data[i+12];
 d2 = data[i+13];
 d3 = Enc2[i+10];
d4 = Enc1[i+10];
tx  = 2*d2 - 2*d3 + 4*d2*d3 - 1.0 + (((2*d2-1)*(2*d3-1))<0?(d4-0.5):(0.5-d4));
tx = (d1 == 0 ? (tx - 4): (4 - tx));
tx = (d0 == 0 ? (tx - 8): (8 - tx));
 rx  = tx + SIGMA_710_1024QAM * gasdev();
L_d0 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
            exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
            exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-11.5)*(rx-11.5)) +
            exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5)))/
           (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
```

```
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)) +
            exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
            exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
            exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
            exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5))));

L_d1 = log((exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
            exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)))/
           (exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
            exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-11.5)*(rx-11.5)) +
            exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5)) +
            exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
            exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
            exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
            exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5))));

L_d2 = log((exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)) +
            exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
            exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
            exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
            exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-11.5)*(rx-11.5)))/
           (exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
            exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5))));

L_d3 = log((exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+7.5)*(rx+7.5)) +
            exp(n*(rx+8.5)*(rx+8.5))+exp(n*(rx+9.5)*(rx+9.5)) +
            exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+15.5)*(rx+15.5)) +
            exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-7.5)*(rx-7.5)) +
            exp(n*(rx-8.5)*(rx-8.5))+exp(n*(rx-9.5)*(rx-9.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-15.5)*(rx-15.5)))/
           (exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+13.5)*(rx+13.5)) +
            exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+11.5)*(rx+11.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-13.5)*(rx-13.5)) +
            exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-10.5)*(rx-10.5))));

L_d4 = log((exp(n*(rx+2.5)*(rx+2.5))+exp(n*(rx+1.5)*(rx+1.5)) +
            exp(n*(rx+6.5)*(rx+6.5))+exp(n*(rx+5.5)*(rx+5.5)) +
            exp(n*(rx+10.5)*(rx+10.5))+exp(n*(rx+9.5)*(rx+9.5)) +
            exp(n*(rx+14.5)*(rx+14.5))+exp(n*(rx+13.5)*(rx+13.5)) +
            exp(n*(rx-2.5)*(rx-2.5))+exp(n*(rx-1.5)*(rx-1.5)) +
            exp(n*(rx-6.5)*(rx-6.5))+exp(n*(rx-5.5)*(rx-5.5)) +
            exp(n*(rx-10.5)*(rx-10.5))+exp(n*(rx-9.5)*(rx-9.5)) +
            exp(n*(rx-14.5)*(rx-14.5))+exp(n*(rx-13.5)*(rx-13.5)))/
           (exp(n*(rx+4.5)*(rx+4.5))+exp(n*(rx+3.5)*(rx+3.5)) +
            exp(n*(rx+7.5)*(rx+7.5))+exp(n*(rx+8.5)*(rx+8.5)) +
            exp(n*(rx+12.5)*(rx+12.5))+exp(n*(rx+11.5)*(rx+11.5)) +
            exp(n*(rx+0.5)*(rx+0.5))+exp(n*(rx+15.5)*(rx+15.5)) +
            exp(n*(rx-4.5)*(rx-4.5))+exp(n*(rx-3.5)*(rx-3.5)) +
            exp(n*(rx-7.5)*(rx-7.5))+exp(n*(rx-8.5)*(rx-8.5)) +
```

```
                    exp(n*(rx-12.5)*(rx-12.5))+exp(n*(rx-11.5)*(rx-11.5)) +
                    exp(n*(rx-0.5)*(rx-0.5))+exp(n*(rx-15.5)*(rx-15.5))));

        D1_data[i+11]   = L_d0;
        D1_data[i+12]   = L_d1;
        D1_data[i+13]   = L_d2;
       D2_parity[i+10] = L_d3;
       D1_parity[i+10] = L_d4;
       D1_parity[i+7]  = 0.0;
       D1_parity[i+8]  = 0.0;
       D1_parity[i+9]  = 0.0;
       D1_parity[i+11] = 0.0;
       D1_parity[i+12] = 0.0;
       D1_parity[i+13] = 0.0;

       i = i+13;
      }
#endif


    /*************************************/


   /*
    * At this moment we received the whole turbo code block:
    * D1_data[] stores the received information sequence,
    * D1_parity[] stores the received punctured parity P sequence and
    * D2_data[] stores the interleaved received information sequence,
    */

    for(i = 0; i < INT_SIZE; i++)
      D2_data[i] = D1_data[i];
    r_ileav(D2_data, rule);
   /*
    * D2_parity[] stores the received punctured parity Q sequence.
    */

    for(iteration = 1; iteration <= NR_ITER; iteration++)
      {
       /*
        * Start one iteration of the turbo decoder here:
        */
#ifdef R46_64QAM_TTCM_VoCAL
       jat_map2(jat_code1, D1_data, D1_parity, D1_app, D1_exi);
#else
       jat_map1(jat_code1, D1_data, D1_parity, D1_app, D1_exi);
#endif
       /*
        * Interleave the extrinsic information from Decoder1:
        */
       for(k = 0; k < INT_SIZE; k++)
         D2_app[k] = D1_exi[k];
       r_ileav(D2_app, rule);

       /*
        * Decoder2:
        */
#ifdef R46_64QAM_TTCM_VoCAL
       jat_map2(jat_code2, D2_data, D2_parity, D2_app, D2_exi);
#else
       jat_map1(jat_code2, D2_data, D2_parity, D2_app, D2_exi);
#endif

       /*
        * Deinterleave the extrinsic information from Decoder2:
        */
       r_deileav(D2_exi, rule);
       for(k = 0; k < INT_SIZE; k++)
         D1_app[k] = D2_exi[k];
```

```
#ifdef R46_64QAM_TTCM_VoCAL
        for(k = 0; k < INT_SIZE/2; k++)
          Dec_data[k] = D1_data[k] + log(D1_exi[k]) + log(D2_exi[k]);

        /*
         * Re-encode with encoder1:
         */
        jat_code1->enc_state = 0;          /* reset encoder1's state    */
        for(k = 0; k < INT_SIZE/2; k++)
          Enc1[k] = jat_enc_bp_fp(jat_code1, ((Dec_data[k] > 0.0)?1:0));

        /*
         * interleave data:
         */
         for(k = 0; k < INT_SIZE/2; k++)
           data_i[k] = ((Dec_data[k] > 0.0)?1:0);
         r_ileava(data_i, rule);

         /*
          * Re-encode with encoder2:
          */
        jat_code2->enc_state = 0;          /* reset encoder2's state    */
        for(k = 0; k < INT_SIZE/2; k++)
            Enc2[k] = jat_enc_bp_fp(jat_code2, data_i[k]);

         /*
          * Find the closest point out of four in the sub-constellation
          */
        for(k = 0; k < INT_SIZE/2 - 1; )
          {
            u4 = ((Dec_data[k] > 0.0)?1:0);
            u3 = ((Dec_data[k+1] > 0.0)?1:0);
            u2 = Enc1[k];
            u1 = Enc2[k+1];

            rx_I = D1_data[k + INT_SIZE/2];
            rx_Q = D1_data[k + INT_SIZE/2 + 1];


            j = 4*u4+8*u3+16*u2+32*u1;
            v00_I = find_tx_I(j);
            v00_Q = find_tx_Q(j);
            v01_I = find_tx_I(j+1);
            v01_Q = find_tx_Q(j+1);
            v10_I = find_tx_I(j+2);
            v10_Q = find_tx_Q(j+2);
            v11_I = find_tx_I(j+3);
            v11_Q = find_tx_Q(j+3);

            Dec_data[k+INT_SIZE/2]  = log(
                    (exp(n*((rx_I-v11_I)*(rx_I-v11_I)+(rx_Q-v11_Q)*(rx_Q-v11_Q)))+
                     exp(n*((rx_I-v10_I)*(rx_I-v10_I)+(rx_Q-v10_Q)*(rx_Q-v10_Q))))/
                    (exp(n*((rx_I-v01_I)*(rx_I-v01_I)+(rx_Q-v01_Q)*(rx_Q-v01_Q)))+
                     exp(n*((rx_I-v00_I)*(rx_I-v00_I)+(rx_Q-v00_Q)*(rx_Q-v00_Q)))));

            Dec_data[k+INT_SIZE/2+1]  = log(
                    (exp(n*((rx_I-v11_I)*(rx_I-v11_I)+(rx_Q-v11_Q)*(rx_Q-v11_Q)))+
                     exp(n*((rx_I-v01_I)*(rx_I-v01_I)+(rx_Q-v01_Q)*(rx_Q-v01_Q))))/
                    (exp(n*((rx_I-v10_I)*(rx_I-v10_I)+(rx_Q-v10_Q)*(rx_Q-v10_Q)))+
                     exp(n*((rx_I-v00_I)*(rx_I-v00_I)+(rx_Q-v00_Q)*(rx_Q-v00_Q)))));

            k = k+2;
          }

#else
        for(k = 0; k < INT_SIZE; k++)
          Dec_data[k] = D1_data[k] + log(D1_exi[k]) + log(D2_exi[k]);
#endif

        /*
```

```
        * print errors:
        */
       k = print_err(data, Dec_data, iteration, block, no_err);
       if(k == 0)
         break;

       /*
        * End one iteration of the turbo decoder here.
        */
     }


  }
free(jat_code1->P0state);
free(jat_code1->P1state);
free(jat_code1->N0state);
free(jat_code1->N1state);
free(jat_code1->Coded0);
free(jat_code1->Coded1);
free(jat_code1);
free(jat_code2->P0state);
free(jat_code2->P1state);
free(jat_code2->N0state);
free(jat_code2->N1state);
free(jat_code2->Coded0);
free(jat_code2->Coded1);
free(jat_code2);
free(rule);
free(data);
free(data_i);
free(data_d);
free(no_err);
free(Enc1);
free(Enc2);
free(D1_data);
free(D1_parity);
free(D1_app);
free(D1_exi);
free(D2_data);
free(D2_parity);
free(D2_app);
free(D2_exi);
free(Dec_data);
free(frame_hist);
free(Zero_data);
for(i = THRESHOLD_ITER; i <= NR_ITER; i++)
       free(bit_hist_array[i]);
free(bit_hist_array);
free(bit_hist_block);
}



/*****************************************************************************/
/* jat_trellis_bp_fp() initializes the code structure                        */
void jat_trellis_bp_fp(jat_code *code_str)
{
  int i;
  for(i = 0; i < code_str->nr_states ; i++)
    {
      code_str->enc_state  = i;
      code_str->P0state[i] = jat_ps(code_str, 0);
      code_str->P1state[i] = jat_ps(code_str, 1);
      code_str->enc_state  = i;
      code_str->Coded0[i]  = jat_enc_bp_fp(code_str, 0);
      code_str->N0state[i] = code_str->enc_state;    /*next state i if d = 0 */
      code_str->enc_state  = i;
      code_str->Coded1[i]  = jat_enc_bp_fp(code_str, 1);
      code_str->N1state[i] = code_str->enc_state;    /*next state i if d = 1 */
    }
}
```

```
/*************************************************************************/
/* jat_ps() returns the previous state, given the code structure & the input */
/*      bit for the previous state                                       */
/*           input:   current state, input bit for the previous state     */
/*           output:  previous state                                      */
int jat_ps(jat_code *code_st, int inp)
{
  int pr_state, pr_msb, i, j, k, l;

  if(code_st->enc_mem == 1)
    {
      pr_state = code_st->enc_state ^ inp;
    }
  else
    {
      /*find previous state:                                              */
      pr_msb = (inp & 0x1) ^ (code_st->enc_state & 0x1);
      for(i=1,j=2,k=(1        <<        code_st->enc_mem-1),l=code_st->enc_mem-1;i<code_st-
>enc_mem;i++,l--)
        {
          pr_msb = pr_msb ^ (((code_st->enc_state&j)>>i) & ((code_st->bp&k)>>l));
          j = j << 1;
          k = k >> 1;
        }

      pr_state = ((code_st->enc_state >> 1) & ((1<<(code_st->enc_mem - 1)) - 1)) |
        (pr_msb << (code_st->enc_mem - 1));
    }
  return (pr_state);
}


/*************************************************************************/
/* jat_enc_bp_fp() -  rate 1/2 systematic feedback convolutional enc.    */
/*           input:  input bit to be encoded                             */
/*           output: the coded bit                                       */
/* Note:     the lsb of the enc_state will have the new input bit        */
/*           the msb of the enc_state matches the lsb of bp & fp         */
int jat_enc_bp_fp(jat_code *code_st, int data)
{
  int new_lsb, parity, i, j, k, l;

  new_lsb = data;
  if(code_st->enc_mem == 1)
    {
      parity = code_st->enc_state ^ data;
      code_st->enc_state = parity;
    }
  else
    {
      /* xor it with the bits of the enc_state1 for which bp1 is one      */
      for(i = 0, j = 1, k = (1 << code_st->enc_mem-1), l = code_st->enc_mem - 1; i <
code_st->enc_mem; i++, l--)
        {
          new_lsb = new_lsb ^ (((code_st->enc_state&j)>>i) & ((code_st->bp&k)>>l));
          j = j << 1;
          k = k >> 1;
        }

      /* find the parity bit                                              */
      parity = new_lsb & ((code_st->fp&(1<<code_st->enc_mem)) >> code_st->enc_mem);
      for(i = 0, j = 1, k = (1 << code_st->enc_mem-1), l = code_st->enc_mem - 1; i <
code_st->enc_mem; i++, l--)
        {
          parity = parity ^ (((code_st->enc_state&j)>>i) & ((code_st->fp&k)>>l));
          j = j << 1;
          k = k >> 1;
        }
```

```
      /* update code_st->enc_state                                          */
      code_st->enc_state  =  ((code_st->enc_state  &  (code_st->nr_states/2  -  1))  <<  1)  |
new_lsb;
    }
  return (parity);
}


/*****************************************************************************/
void r_ileav(double *array, int *rule_i)
{
  double *i_wmem;
  int    k;

  i_wmem = (double *)malloc(sizeof(double) * INT_SIZE);
  if(i_wmem == 0)
    printf("\nCouldn't allocate i_wmem memory!");
  for(k = 0; k < INT_SIZE; k++)
    i_wmem[k] = array[k];
  for(k = 0; k < INT_SIZE; k++)
    array[k] = i_wmem[rule_i[2*k+1]];
  free(i_wmem);
}


/*****************************************************************************/
void r_ileava(int *array, int *rule_i)
{
  int   *i_wmem;
  int   k;

  i_wmem = (int *)malloc(sizeof(int) * INT_SIZE);
  if(i_wmem == 0)
    printf("\nCouldn't allocate i_wmem memory!");
  for(k = 0; k < INT_SIZE; k++)
    i_wmem[k] = array[k];
  for(k = 0; k < INT_SIZE; k++)
    array[k] = i_wmem[rule_i[2*k+1]];
  free(i_wmem);
}


/*****************************************************************************/
void r_deileav(double *array, int *rule_d)
{
  double *d_wmem;
  int    k;

  d_wmem = (double *)malloc(sizeof(double) * INT_SIZE);
  if(d_wmem == 0)
    printf("\nCouldn't allocate d_wmem memory!");
  for(k = 0; k < INT_SIZE; k++)
    d_wmem[rule_d[2*k+1]] = array[k];
  for(k = 0; k < INT_SIZE; k++)
    array[k] = d_wmem[k];
  free(d_wmem);
}


/*****************************************************************************/
void r_deileava(int *array, int *rule_d)
{
  int    *d_wmem;
  int    k;

  d_wmem = (int *)malloc(sizeof(int) * INT_SIZE);
  if(d_wmem == 0)
    printf("\nCouldn't allocate d_wmem memory!");
  for(k = 0; k < INT_SIZE; k++)
    d_wmem[rule_d[2*k+1]] = array[k];
  for(k = 0; k < INT_SIZE; k++)
```

```
    array[k] = d_wmem[k];
  free(d_wmem);
}


/*****************************************************************************/
/* nrgen() returns a random number between 0 and 1                           */
/*         (uniform distribution generator)                                  */
double nrgen()
{
  long z, k;

  k = s1 / 53668;
  s1 = 40014 * (s1 - k * 53668) - k * 12211;
  if(s1 < 0)
    s1 += 2147483563;
  k = s2 / 52774;
  s2 = 40692 * (s2 - k * 52774) - k * 3791;
  if(s2 < 0)
    s2 += 2147483399;
  z = s1 - s2;
  if(z < 1)
    z += 2147483562;
  return ((double)z / 2147483563);
}


/*****************************************************************************/
/* nrgenbin() returns a 0 or 1 (uniform distribution)                        */
int nrgenbin()
{
  return ((nrgen() > 0.5)?1:0);
}


/*****************************************************************************/
/* gasdev() returns a normally distributed deviate                           */
/*          with zero mean and unit variance                                 */
double gasdev()
{
  static int     iset = 0;
  static double  gset;
  double         fac, r, v1, v2;

  if(iset == 0)
    {
      /* pick two uniform numbers in the square extending from               */
      /* -1 to +1 in each direction, see if they are in the                  */
      /* unit circle, and if they are not, try again.                        */
      do
        {
          v1 = 2.0 * nrgen() - 1.0;
          v2 = 2.0 * nrgen() - 1.0;
         r = v1 * v1 + v2 * v2;
        }
      while (r >= 1.0 || r == 0.0);
      fac = sqrt(-2.0 * log(r)/r);
      /* now make the Box-Muller transformation to get two normal            */
      /* deviates; return one and save the other for next time.              */
      gset = v1 * fac;
      iset = 1;              /* set flag                                     */
      return (v2 * fac);
    }
  else
    {
      /* we have an extra deviate handy, so unset the flag and               */
      /* return it.                                                          */
      iset = 0;
      return (gset);
    }
}
```

```
/*****************************************************************************/
/* errors() returns the nr. of positions in which two blocks of data are     */
/*          different; it accepts a shift between the addresses              */
/*          inputs: the address of the first block of integers                */
/*                  the address of the second block of doubles                */
/*                  the size of the block (blocks are equal)                  */
/*          output: the number of positions in which the two blocks are dif. */
int errors(int *block1, double *block2, int size, int iter_nr)
{
  int  i;
  int  count = 0;

  for(i = 0; i < size; i++)
      if(block1[i] != ((block2[i] > 0.0)?1:0))
        {
          count++;
#if defined BIT_HIST
          if(iter_nr>=THRESHOLD_ITER)
            {
              *bit_hist_array[iter_nr] = bit_hist_block[iter_nr];
              bit_hist_array[iter_nr]++;
              *bit_hist_array[iter_nr] = i;
              bit_hist_array[iter_nr]++;
            }
#endif
        }
#if defined BIT_HIST
  if((count>0)&&(iter_nr >= THRESHOLD_ITER))
    bit_hist_block[iter_nr]++;
#endif
  return (count);
}


/*****************************************************************************/
/* print_err() append to the file the nr. of errors and BER                  */
/* returns:  number of bit errors in a block                                 */
int print_err(int *data1, double *data2, int iter_no, int block_no, int *err)
{
  int   i, j, nr;
  int   block_err = 0;
  char fname[] = BIT_HIST_FILE_NAME;
  char sss[] = {'0','1','2','3','4','5','6','7','8','9'};
  FILE  *out_file = NULL;
  int   *pi;

  if((iter_no == 1) && (block_no == 1))
    {
      out_file = fopen(ERROR_FILE_NAME, "a");
      if(!out_file)
        {
          printf("Error2: the output file could not be opened!\n");
          exit (1);
        }
      fprintf(out_file,  "ref_tc.c,  RSC1_enc_mem  =  %d,  RSC1_fp  =  %d,  RSC1_bp  =  %d,
RSC2_enc_mem = %d, RSC2_fp = %d, RSC2_bp = %d, s1 = %d, s2 = %d, int_size = %d, Limit soft
outputs to = %e, Eb/No = %fdB\n", RSC1_ENC_MEM, RSC1_FP, RSC1_BP, RSC2_ENC_MEM, RSC2_FP,
RSC2_BP, SEED1, SEED2, INT_SIZE, (double) MAX, (double) EBNO);
      fclose(out_file);
    }
  block_err = errors(data1, data2, INT_SIZE, iter_no);
  err[iter_no - 1] += block_err;

  ++frame_hist[(iter_no-1)*(INT_SIZE+1) + block_err];

  if((iter_no == NR_ITER) && (block_err != 0))
    ++frame_err;
```

```
#if defined BIT_HIST
  if((block_err != 0) && (iter_no >= THRESHOLD_ITER))
    {
      fname[strlen(fname)-1]= sss[iter_no];
      out_file = fopen(fname, "a");
      if(!out_file)
        {
          printf("Error: the bit_hist file could not be opened!\n");
          exit (1);
        }
      for(pi = bit_hist_array[NR_ITER +iter_no]; pi < bit_hist_array[iter_no]; pi = pi+2)
        fprintf(out_file, "\n%06d %06d", *pi, *(pi+1));
      fclose(out_file);
      bit_hist_array[iter_no] = bit_hist_array[NR_ITER +iter_no];
    }
#endif

  if(((iter_no == NR_ITER) && (((block_no % PRINT_BLOCKS) == 0) || (err[NR_ITER - 1] >
MAX_ERRORS))) || (((block_no % PRINT_BLOCKS) == 0) && (block_err == 0)))


      {
        out_file = fopen(ERROR_FILE_NAME, "a");
        if(!out_file)
          {
            printf("Error3: the output file could not be opened!\n");
            exit (1);
          }
        nr = block_no * INT_SIZE;
        fprintf(out_file, "\n\nNr. of info bits:  %d (%d blocks)",
                nr, block_no);
        for(j = 0; j < NR_ITER; j++)
          fprintf(out_file, "\nIter: %02d, Errors: %06d, BER = %e",
                  j + 1, err[j],(double)err[j]/INT_SIZE/block_no);
        total_err = err[NR_ITER - 1];
        fprintf(out_file, "\nFrame error = %f(%f errors per block)\n",
                (double)frame_err/block_no,
                (frame_err == 0?0.0:(double)err[NR_ITER-1]/frame_err));
        fclose(out_file);

        if((block_no % 100000) == 0)
          {
            out_file = fopen(FRAME_HIST_FILE_NAME, "a");
            if(!out_file)
              {
                printf("Error4: the .fhist file could not be opened!\n");
                exit (1);
              }
            nr = block_no * INT_SIZE;
            fprintf(out_file, "\n\nNr. of info bits:  %d (%d blocks)",
                    nr, block_no);
            for(j = 0; j <= INT_SIZE; j++)
              fprintf(out_file, "\n%03d %03d",
                      j, frame_hist[(NR_ITER-1)*(INT_SIZE+1)+j]);
            fclose(out_file);
          }
      }
return (block_err);
}


/*****************************************************************************/
/* This is a MAP decoder for a cs->nr_states states jat_code.                */
/*   function:  decodes a block of received data of length INT_SIZE.         */
/*              It assumes that the encoder state starts from state zero     */
/*   input:     code structure, I address, Q address, L_in address           */
/*   output:    the extrinsic information in L_out                           */
/*   globals:   noise                                                        */
```

```
/*
 ****************************************************************************
 * As jat_map but outputs probability and not log(probability)
 * It also can handle very large interleavers
 */
void jat_mapl(jat_code *cs, double *I, double *Q, double *L_in, double *L_out)
{
  double    sum, sum_0, sum_1, max;
  int       i, j, k, st;
  double    *alpha_old;
  double    *alpha_new;
  double    *beta0;
  double    *beta1;
  double    *probI;
  double    *probQ;

alpha_old = (double *)malloc(sizeof(double) * 2 * cs->nr_states);
alpha_new = (double *)malloc(sizeof(double) * 2 * cs->nr_states);

beta0 = (double *)malloc(sizeof(double) * INT_SIZE * cs->nr_states);
if(beta0 == 0)
  {
    printf("Couldn't allocate beta0 memory!\n");
    exit(1);
  }

beta1 = (double *)malloc(sizeof(double) * INT_SIZE * cs->nr_states);
if(beta1 == 0)
  {
    printf("Couldn't allocate beta1 memory!\n");
    exit(1);
  }

probI = (double *)malloc(sizeof(double) * INT_SIZE);
if(probI == 0)
  {
    printf("Couldn't allocate probI memory!\n");
    exit(1);
  }

probQ = (double *)malloc(sizeof(double) * INT_SIZE);
if(probQ == 0)
  {
    printf("Couldn't allocate probQ memory!\n");
    exit(1);
  }


  /* initialize the alpha_old metrics                                    */
  for(st = 0; st < cs->nr_states; st++)
    for(k = 0; k < 2; k++)
      *(alpha_old + k * cs->nr_states + st) = 0.0;

  *(alpha_old + cs->P0state[0]) = 1.0;
  *(alpha_old + cs->nr_states + cs->P1state[0]) = 1.0;

  /* initialize beta's                                                   */
  for(st = 0; st < cs->nr_states; st++)
    {
      beta0[(INT_SIZE - 1) * cs->nr_states + st] = 1.0;
      beta1[(INT_SIZE - 1) * cs->nr_states + st] = 1.0;
    }

  /* compute all beta's                                                  */
  for(i = INT_SIZE - 2; i >= 0; i--)
      {
        probI[i + 1] = exp(I[i + 1]) * L_in[i + 1];
        probQ[i + 1] = exp(Q[i + 1]);
        for(st = 0; st < cs->nr_states; st++)
          {
            /* compute beta0[i][st]:                                     */
```

```
              beta0[i * cs->nr_states + st] = beta0[(i + 1) * cs->nr_states + cs-
>N0state[st]]*
                          ((cs->Coded0[cs->N0state[st]] == 0)?1:probQ[i + 1])+
                          beta1[(i + 1) * cs->nr_states + cs->N0state[st]]*probI[i + 1]*
                          ((cs->Coded1[cs->N0state[st]] == 0)?1:probQ[i + 1]);
              beta1[i * cs->nr_states + st] = beta0[(i + 1) * cs->nr_states + cs-
>N1state[st]]*
                          ((cs->Coded0[cs->N1state[st]] == 0)?1:probQ[i + 1])+
                          beta1[(i + 1) * cs->nr_states + cs->N1state[st]]*probI[i + 1]*
                          ((cs->Coded1[cs->N1state[st]] == 0)?1:probQ[i + 1]);
          }

        max = beta0[i * cs->nr_states];
        for(st = 1; st < cs->nr_states; st++)
          if(beta0[i * cs->nr_states + st] > max)
            max = beta0[i * cs->nr_states + st];
        for(st = 0; st < cs->nr_states; st++)
          if(beta1[i * cs->nr_states + st] > max)
            max = beta1[i * cs->nr_states + st];
        for(st = 0; st < cs->nr_states; st++)
          {
            beta0[i * cs->nr_states + st] = beta0[i * cs->nr_states + st] / max;
            beta1[i * cs->nr_states + st] = beta1[i * cs->nr_states + st] / max;
          }
      }

  /* now we have all beta's; we can compute alpha for all states for each    */
  /* data bit and using beta's we compute lambda                             */
  probI[0] = exp(I[0]) * L_in[0];
  probQ[0] = exp(Q[0]);
  for(k = 0; k < INT_SIZE; k++)
    {
      for(st = 0; st < cs->nr_states; st++)
        {
        sum = *(alpha_old + cs->P0state[st]) + *(alpha_old + cs->nr_states + cs-
>P1state[st]);
        *(alpha_new + st) = sum * ((cs->Coded0[st] == 0)?1:probQ[k]);
        *(alpha_new + cs->nr_states + st) = sum * probI[k] * ((cs->Coded1[st] ==
0)?1:probQ[k]);
        }

      /* find the max value and renormalize alpha's:                         */
      max = *alpha_new;
      for(st = 0; st < cs->nr_states; st++)
        for(j = 0; j < 2; j++)
          if(*(alpha_new + cs->nr_states * j + st) > max)
                max = *(alpha_new + cs->nr_states * j + st);
      for(st = 0; st < cs->nr_states; st++)
        for(j = 0; j < 2; j++)
          *(alpha_new + cs->nr_states * j + st) = *(alpha_new + cs->nr_states * j + st)/
max;

      /* find sum_0 and sum_1 over all states for L_out:                     */
      sum_0 = 0.0;
      sum_1 = 0.0;
      for(st = 0; st < cs->nr_states; st++)
        {
          sum_0 += *(alpha_new + st) * beta0[k * cs->nr_states + st];
          sum_1 += *(alpha_new + cs->nr_states + st) * beta1[k * cs->nr_states + st];
        }

      /* output the extrinsic information:                                  */
      L_out[k] = (sum_1 / sum_0) / exp(I[k]) / L_in[k];
      if(L_out[k] > MAX)
        L_out[k] = MAX;
      if(L_out[k] < 1/MAX)
        L_out[k] = 1/MAX;

      for(st = 0; st < cs->nr_states; st++)
        for(j = 0; j < 2; j++)/* update alphas          */
          *(alpha_old + cs->nr_states * j + st)=*(alpha_new + cs->nr_states * j + st);
```

```
    }
free(beta0);
free(beta1);
free(probI);
free(probQ);
free(alpha_old);
free(alpha_new);
}



double find_tx_I(int k)
{
  double tx_I;
        switch(k)
          {
          case 0:
            tx_I = 0.5;
            break;
          case 1:
            tx_I = -3.5;
            break;
          case 2:
            tx_I = 0.5;
            break;
          case 3:
            tx_I = -3.5;
            break;
          case 4:
            tx_I = 2.5;
            break;
          case 5:
            tx_I = -1.5;
            break;
          case 6:
            tx_I = 2.5;
            break;
          case 7:
            tx_I = -1.5;
            break;
          case 8:
            tx_I = 2.5;
            break;
          case 9:
            tx_I = -1.5;
            break;
          case 10:
            tx_I = 2.5;
            break;
          case 11:
            tx_I = -1.5;
            break;
          case 12:
            tx_I = 0.5;
            break;
          case 13:
            tx_I = -3.5;
            break;
          case 14:
            tx_I = 0.5;
            break;
          case 15:
            tx_I = -3.5;
            break;
          case 16:
            tx_I = 1.5;
            break;
          case 17:
            tx_I = -2.5;
            break;
```

```
case 18:
  tx_I = 1.5;
  break;
case 19:
  tx_I = -2.5;
  break;
case 20:
  tx_I = 3.5;
  break;
case 21:
  tx_I = -0.5;
  break;
case 22:
  tx_I = 3.5;
  break;
case 23:
  tx_I = -0.5;
  break;
case 24:
  tx_I = 3.5;
  break;
case 25:
  tx_I = -0.5;
  break;
case 26:
  tx_I = 3.5;
  break;
case 27:
  tx_I = -0.5;
  break;
case 28:
  tx_I = 1.5;
  break;
case 29:
  tx_I = -2.5;
  break;
case 30:
  tx_I = 1.5;
  break;
case 31:
  tx_I = -2.5;
  break;
case 32:
  tx_I = 1.5;
  break;
case 33:
  tx_I = -2.5;
  break;
case 34:
  tx_I = 1.5;
  break;
case 35:
  tx_I = -2.5;
  break;
case 36:
  tx_I = 3.5;
  break;
case 37:
  tx_I = -0.5;
  break;
case 38:
  tx_I = 3.5;
  break;
case 39:
  tx_I = -0.5;
  break;
case 40:
  tx_I = 3.5;
  break;
case 41:
  tx_I = -0.5;
```

```
        break;
      case 42:
        tx_I = 3.5;
        break;
      case 43:
        tx_I = -0.5;
        break;
      case 44:
        tx_I = 1.5;
        break;
      case 45:
        tx_I = -2.5;
        break;
      case 46:
        tx_I = 1.5;
        break;
      case 47:
        tx_I = -2.5;
        break;
      case 48:
        tx_I = 0.5;
        break;
      case 49:
        tx_I = -3.5;
        break;
      case 50:
        tx_I = 0.5;
        break;
      case 51:
        tx_I = -3.5;
        break;
      case 52:
        tx_I = 2.5;
        break;
      case 53:
        tx_I = -1.5;
        break;
      case 54:
        tx_I = 2.5;
        break;
      case 55:
        tx_I = -1.5;
        break;
      case 56:
        tx_I = 2.5;
        break;
      case 57:
        tx_I = -1.5;
        break;
      case 58:
        tx_I = 2.5;
        break;
      case 59:
        tx_I = -1.5;
        break;
      case 60:
        tx_I = 0.5;
        break;
      case 61:
        tx_I = -3.5;
        break;
      case 62:
        tx_I = 0.5;
        break;
      case 63:
        tx_I = -3.5;
        break;
      }
    return(tx_I);
}
```

```
double find_tx_Q(int k)
{
  double tx_Q;
        switch(k)
          {
          case 0:
            tx_Q = 2.5;
            break;
          case 1:
            tx_Q = 2.5;
            break;
          case 2:
            tx_Q = -1.5;
            break;
          case 3:
            tx_Q = -1.5;
            break;
          case 4:
            tx_Q = 0.5;
            break;
          case 5:
            tx_Q = 0.5;
            break;
          case 6:
            tx_Q = -3.5;
            break;
          case 7:
            tx_Q = -3.5;
            break;
          case 8:
            tx_Q = 2.5;
            break;
          case 9:
            tx_Q = 2.5;
            break;
          case 10:
            tx_Q = -1.5;
            break;
          case 11:
            tx_Q = -1.5;
            break;
          case 12:
            tx_Q = 0.5;
            break;
          case 13:
            tx_Q = 0.5;
            break;
          case 14:
            tx_Q = -3.5;
            break;
          case 15:
            tx_Q = -3.5;
            break;
          case 16:
            tx_Q = 3.5;
            break;
          case 17:
            tx_Q = 3.5;
            break;
          case 18:
            tx_Q = -0.5;
            break;
          case 19:
            tx_Q = -0.5;
            break;
          case 20:
            tx_Q = 1.5;
            break;
          case 21:
            tx_Q = 1.5;
```

```
    break;
  case 22:
    tx_Q = -2.5;
    break;
  case 23:
    tx_Q = -2.5;
    break;
  case 24:
    tx_Q = 3.5;
    break;
  case 25:
    tx_Q = 3.5;
    break;
  case 26:
    tx_Q = -0.5;
    break;
  case 27:
    tx_Q = -0.5;
    break;
  case 28:
    tx_Q = 1.5;
    break;
  case 29:
    tx_Q = 1.5;
    break;
  case 30:
    tx_Q = -2.5;
    break;
  case 31:
    tx_Q = -2.5;
    break;
  case 32:
    tx_Q = 2.5;
    break;
  case 33:
    tx_Q = 2.5;
    break;
  case 34:
    tx_Q = -1.5;
    break;
  case 35:
    tx_Q = -1.5;
    break;
  case 36:
    tx_Q = 0.5;
    break;
  case 37:
    tx_Q = 0.5;
    break;
  case 38:
    tx_Q = -3.5;
    break;
  case 39:
    tx_Q = -3.5;
    break;
  case 40:
    tx_Q = 2.5;
    break;
  case 41:
    tx_Q = 2.5;
    break;
  case 42:
    tx_Q = -1.5;
    break;
  case 43:
    tx_Q = -1.5;
    break;
  case 44:
    tx_Q = 0.5;
    break;
  case 45:
```

```
            tx_Q = 0.5;
            break;
          case 46:
            tx_Q = -3.5;
            break;
          case 47:
            tx_Q = -3.5;
            break;
          case 48:
            tx_Q = 3.5;
            break;
          case 49:
            tx_Q = 3.5;
            break;
          case 50:
            tx_Q = -0.5;
            break;
          case 51:
            tx_Q = -0.5;
            break;
          case 52:
            tx_Q = 1.5;
            break;
          case 53:
            tx_Q = 1.5;
            break;
          case 54:
            tx_Q = -2.5;
            break;
          case 55:
            tx_Q = -2.5;
            break;
          case 56:
            tx_Q = 3.5;
            break;
          case 57:
            tx_Q = 3.5;
            break;
          case 58:
            tx_Q = -0.5;
            break;
          case 59:
            tx_Q = -0.5;
            break;
          case 60:
            tx_Q = 1.5;
            break;
          case 61:
            tx_Q = 1.5;
            break;
          case 62:
            tx_Q = -2.5;
            break;
          case 63:
            tx_Q = -2.5;
            break;
          }
        return(tx_Q);
}


/*************************************************************************/
/* This is a MAP decoder for a cs->nr_states states jat_code.            */
/*   function:  decodes a block of received data of length INT_SIZE/2.    */
/*              It assumes that the encoder state starts from state zero  */
/*   input:     code structure, I address, Q address, L_in address        */
/*   output:    the extrinsic information in L_out                        */
/*   globals:   noise                                                     */


/*
```

```
/*****************************************************************************
 * As jat_map but outputs probability and not log(probability)
 * It also can handle very large interleavers
 */
void jat_map2(jat_code *cs, double *I, double *Q, double *L_in, double *L_out)
{
  double    sum, sum_0, sum_1, max;
  int       i, j, k, st;
  double    *alpha_old;
  double    *alpha_new;
  double    *beta0;
  double    *beta1;
  double    *probI;
  double    *probQ;

alpha_old = (double *)malloc(sizeof(double) * 2 * cs->nr_states);
alpha_new = (double *)malloc(sizeof(double) * 2 * cs->nr_states);

beta0 = (double *)malloc(sizeof(double) * INT_SIZE/2 * cs->nr_states);
if(beta0 == 0)
  {
    printf("Couldn't allocate beta0 memory!\n");
    exit(1);
  }

beta1 = (double *)malloc(sizeof(double) * INT_SIZE/2 * cs->nr_states);
if(beta1 == 0)
  {
    printf("Couldn't allocate beta1 memory!\n");
    exit(1);
  }

probI = (double *)malloc(sizeof(double) * INT_SIZE/2);
if(probI == 0)
  {
    printf("Couldn't allocate probI memory!\n");
    exit(1);
  }

probQ = (double *)malloc(sizeof(double) * INT_SIZE/2);
if(probQ == 0)
  {
    printf("Couldn't allocate probQ memory!\n");
    exit(1);
  }


  /* initialize the alpha_old metrics                                        */
  for(st = 0; st < cs->nr_states; st++)
    for(k = 0; k < 2; k++)
      *(alpha_old + k * cs->nr_states + st) = 0.0;

  *(alpha_old + cs->P0state[0]) = 1.0;
  *(alpha_old + cs->nr_states + cs->P1state[0]) = 1.0;

  /* initialize beta's                                                       */
  for(st = 0; st < cs->nr_states; st++)
    {
      beta0[(INT_SIZE/2 - 1) * cs->nr_states + st] = 1.0;
      beta1[(INT_SIZE/2 - 1) * cs->nr_states + st] = 1.0;
    }

  /* compute all beta's                                                      */
  for(i = INT_SIZE/2 - 2; i >= 0; i--)
      {
        probI[i + 1] = exp(I[i + 1]) * L_in[i + 1];
        probQ[i + 1] = exp(Q[i + 1]);
        for(st = 0; st < cs->nr_states; st++)
          {
            /* compute beta0[i][st]:                                       */
```

```
              beta0[i * cs->nr_states + st] = beta0[(i + 1) * cs->nr_states + cs-
>N0state[st]]*
                          ((cs->Coded0[cs->N0state[st]] == 0)?1:probQ[i + 1])+
                          beta1[(i + 1) * cs->nr_states + cs->N0state[st]]*probI[i + 1]*
                          ((cs->Coded1[cs->N0state[st]] == 0)?1:probQ[i + 1]);
              beta1[i * cs->nr_states + st] = beta0[(i + 1) * cs->nr_states + cs-
>N1state[st]]*
                          ((cs->Coded0[cs->N1state[st]] == 0)?1:probQ[i + 1])+
                          beta1[(i + 1) * cs->nr_states + cs->N1state[st]]*probI[i + 1]*
                          ((cs->Coded1[cs->N1state[st]] == 0)?1:probQ[i + 1]);
          }

        max = beta0[i * cs->nr_states];
        for(st = 1; st < cs->nr_states; st++)
          if(beta0[i * cs->nr_states + st] > max)
            max = beta0[i * cs->nr_states + st];
        for(st = 0; st < cs->nr_states; st++)
          if(beta1[i * cs->nr_states + st] > max)
            max = beta1[i * cs->nr_states + st];
        for(st = 0; st < cs->nr_states; st++)
          {
            beta0[i * cs->nr_states + st] = beta0[i * cs->nr_states + st] / max;
            beta1[i * cs->nr_states + st] = beta1[i * cs->nr_states + st] / max;
          }
      }

  /* now we have all beta's; we can compute alpha for all states for each    */
  /* data bit and using beta's we compute lambda                             */
  probI[0] = exp(I[0]) * L_in[0];
  probQ[0] = exp(Q[0]);
  for(k = 0; k < INT_SIZE/2; k++)
    {
      for(st = 0; st < cs->nr_states; st++)
        {
        sum = *(alpha_old + cs->P0state[st]) + *(alpha_old + cs->nr_states + cs-
>P1state[st]);
        *(alpha_new + st) = sum * ((cs->Coded0[st] == 0)?1:probQ[k]);
        *(alpha_new + cs->nr_states + st) = sum * probI[k] * ((cs->Coded1[st] ==
0)?1:probQ[k]);
        }

      /* find the max value and renormalize alpha's:                         */
      max = *alpha_new;
      for(st = 0; st < cs->nr_states; st++)
        for(j = 0; j < 2; j++)
          if(*(alpha_new + cs->nr_states * j + st) > max)
                max = *(alpha_new + cs->nr_states * j + st);
      for(st = 0; st < cs->nr_states; st++)
        for(j = 0; j < 2; j++)
          *(alpha_new + cs->nr_states * j + st) = *(alpha_new + cs->nr_states * j + st)/
max;

      /* find sum_0 and sum_1 over all states for L_out:                     */
      sum_0 = 0.0;
      sum_1 = 0.0;
      for(st = 0; st < cs->nr_states; st++)
        {
          sum_0 += *(alpha_new + st) * beta0[k * cs->nr_states + st];
          sum_1 += *(alpha_new + cs->nr_states + st) * beta1[k * cs->nr_states + st];
        }

      /* output the extrinsic information:                                  */
      L_out[k] = (sum_1 / sum_0) / exp(I[k]) / L_in[k];
      if(L_out[k] > MAX)
        L_out[k] = MAX;
      if(L_out[k] < 1/MAX)
        L_out[k] = 1/MAX;

      for(st = 0; st < cs->nr_states; st++)
        for(j = 0; j < 2; j++)/* update alphas          */
          *(alpha_old + cs->nr_states * j + st)=*(alpha_new + cs->nr_states * j + st);
```

```
    }
free(beta0);
free(beta1);
free(probI);
free(probQ);
free(alpha_old);
free(alpha_new);
}
```

interlever.c

```
#define MAX_CINDEX 46
#define MAX_RINDEX 47
#define MAX_ELEMENT 2100
#include <stdio.h>
#include <stdlib.h>

void main (void)
{
        int ra, ca; //Ia sequence row and column indices
        int count; //Counter for each bit in DMT frame
        int element; //Element number used for finding if element within array
        FILE *output;


        output=fopen("interleaver","w");
        //Initial sequence indices

        ra=MAX_RINDEX-1;
        ca=0;

        //Adjust the initial indices for Ia if beyond ending element

        element=ra*MAX_CINDEX+ca;

        while (element >=MAX_ELEMENT) {
                ra--;
                ca++;
                if (ra<0) {
                        ra=MAX_RINDEX-1;
                        ca=ca+(MAX_RINDEX-1);
                }
                ca=ca%MAX_CINDEX;

                element= ra*MAX_CINDEX+ra;
        }

        //Fetch all elements in sequence Ia

        for (count = 0; count<MAX_ELEMENT; count++) {
                //Fetch array[ra][ca]
                element=ra*MAX_CINDEX+ca;
                fprintf(output,"%d %d\n",count,element);
                //Update indices for next access

                do {
                        ra--;
                        ca++;
                        if (ra<0) {
                                ra=MAX_RINDEX-1;
                                ca=ca+(MAX_RINDEX-1);
                        }
                        ca=ca%MAX_CINDEX;

                        element = ra * MAX_CINDEX+ca;
                } while (element >= MAX_ELEMENT);
        }
}
```

S-type interleaver generatior

```
program int(input,output);
{This program generates mod-k S-random and symmetric mod-k S-random interleavers.

const Nmax = 65536; {maximum interleaver size}

var G,H,I,J,K,L,M,N,S,count,temp,prt,i_,j_,k_,im,jm:longint;
    inta,hat,deint:array[0..Nmax] of longint;
    pass,good:boolean;
    s1,s2:longint; {seeds for function uniform}
    into,deinto:text;
    sym:char;

function max(x,y:longint):longint;
{Finds the maximum of x and y}
begin{max}
  if x > y
    then max := x
    else max := y;
end;{max}

function min(x,y:longint):longint;
{Finds the maximum of x and y}
begin{min}
  if x < y
    then min := x
    else min := y;
end;{min}

function uniform(var s1,s2:longint):double;
{Generates a random number from 0.0 < x < 1.0}
const m0 = 2147483562;
      m1 = 2147483563;
      m2 = 2147483399;
      a1 = 40014;
      a2 = 40692;
      q1 = 53668;
      q2 = 52774;
      r1 = 12211;
      r2 =  3791;
var k:longint;
begin{uniform}
  k := s1 div q1;
  s1 := a1*(s1-k*q1) - k*r1;
  if s1 < 0 then s1 := s1+m1;

  k := s2 div q2;
  s2 := a2*(s2-k*q2) - k*r2;
  if s2 < 0 then s2 := s2+m2;

  k := s1-s2;
  if k < 1 then k := k+m0;
  uniform := k/m1;
end;{uniform}

procedure srandom;
{Generates mod-k S-random interleaver}
label 98;

procedure reject;
{reject random number}
begin{reject}
  count := count-1;
  if count = 0
    then begin{bad int}
           good := false;
           goto 98;
         end;{bad int}
```

```
  pass := false;
  for M := K to count-1 do
    hat[M] := hat[M+1];
  hat[count] := J;
end;{reject}

begin{S-random}
  repeat
    writeln('seed1 = ',s1:1,', seed2 = ',s2:1);
    good := true;
    for I := 0 to N-1 do
      hat[I] := I;
    for I := 0 to N-1 do
      begin{make int}
        count := N-I;
        i_ := I mod k_;
        im := min(i_,k_-i_);
        repeat
          pass := true;
          K := trunc(count*uniform(s1,s2));
          if K = count then K := K-1;
          J := hat[K];
          if k_ > 1 then
            begin{mod k test}
              j_ := J mod k_;
              jm := min(j_,k_-j_);
              if im <> jm then reject;
            end;{mod k test}
          if pass = true then
            begin{S-random test}
              for L := max(0,I-S) to I-1 do
                if (abs(J-inta[L]) <= S) and (pass = true) then reject;
            end{S-random test}
        until pass = true;
        for M := K to N-I-2 do
          hat[M] := hat[M+1];
        inta[I] := J;
      end;{make int}
    98:
  until good = true;
end{S-random};

procedure trandom;
{Generates symmetric mod-k S-random interleaver}
label 99;

procedure rejectS;
{reject random number}
begin{reject S}
  count := count-1;
  if count = 0 then
    begin{bad int}
      good := false;
      goto 99;
    end;{bad int}
  pass := false;
  inta[I] := -1;
  inta[J] := -1;
  for M := K to count-1 do
    hat[M] := hat[M+1];
  hat[count] := J;
end;{reject S}

procedure test;
{S-random test}
begin{test}
  if (inta[L] >= 0) and (abs(G-inta[L]) <= S) then rejectS;
  L := L+1;
end;{test}

begin{T-random}
```

```
  repeat
    writeln('seed1 = ',s1:1,', seed2 = ',s2:1);
    good := true;
    for I := 0 to N-1 do
      begin{init}
        hat[I] := I;
        inta[I] := -1;
      end;{init}
    H := N;
    I := 0;
    repeat
      count := H;
      while (inta[I] >= 0) and (I < N) do I := I+1;
      i_ := I mod k_;
      im := min(i_,k_-i_);
      repeat
        pass := true;
        K := trunc(count*uniform(s1,s2));
        if K = count then K := K-1;
        J := hat[K];
        if k_ > 1 then
          begin{mod k test}
            j_ := J mod k_;
            jm := min(j_,k_-j_);
            if im <> jm then rejectS;
          end;{mod k test}
        if pass = true then
          begin{S-random test}
            inta[I] := J;
            inta[J] := I;
            G := J;
            L := max(0,I-S);
            while (pass = true) and (L < I) do test;
            L := I+1;
            while (pass = true) and (L < min(I+S,N)) do test;
            G := I;
            L := max(0,J-S);
            while (pass = true) and (L < J) do test;
            L := J+1;
            while (pass = true) and (L < min(J+S,N)) do test;
          end;{S-random test}
      until pass = true;

      H := H-1;
      for M := K to H-1 do
        hat[M] := hat[M+1];
      if I <> J then
        begin{sym}
          K := 0;
          while (hat[K] <> I) and (K < H) do K := K+1;
          H := H-1;
          for M := K to H-1 do
            hat[M] := hat[M+1];
        end;{sym}
    until H = 0;
    99:
  until good = true;
end{T-random};

begin{int}
  s1 := 12345; {initialise seeds for uniform}
  s2 := 67890;

  writeln;
  writeln('Random Interleaver Generator V1.01');
  writeln('Copyright (c) 1998 Small World Communications. All rights reserved.');
  writeln;
  write('Enter block size N <= ',Nmax:1,': ');
  readln(N);
  write('Enter S parameter (S=1 is random): ');
  readln(S);
```

```
  write('Enter mod-k parameter (k=1 is normal): ');
  readln(k_);
  repeat
    write('Do you want a symmetric interleaver? ');
    readln(sym);
    pass := (sym = 'y') or (sym = 'Y') or (sym = 'n') or (sym = 'N');
    if pass = false then
      writeln('Invalid entry. Try again.');
  until pass = true;
  writeln;
  case sym of
    'y','Y': trandom;
    'n','N': srandom;
  end;{case}

  assign(into,'int.dat');
  rewrite(into);
  for I := 0 to N-1 do
    writeln(into,inta[I]:1);
  close(into);

  for I := 0 to N-1 do
    hat[I] := 0;
  for I := 0 to N-1 do
    begin{test}
      J := inta[I];
      hat[J] := hat[J] + 1;
    end;{test}
  pass := true;
  for I := 0 to N-1 do
    if hat[I] < 1 then pass := false;
  if pass = false
    then writeln('Bad interleaver!');

  pass := true;
  I := 0;
  repeat
    J := inta[I];
    for L := max(0,I-S) to I-1 do
      if (abs(J-inta[L]) <= S) and (pass = true)
        then begin
               pass := false;
               writeln('Interleaver failed S-test');
               writeln(I:1,' ',inta[I]:1,' ',L:1,' ',inta[L]:1);
             end;
    I := I+1;
  until (pass = false) or (I = N);

  K := 0;
  for I := 0 to N-1 do
    K := max(K,abs(I-inta[I]));
  writeln('Dmin = ',K:1);
  writeln('Interleaver table int.dat successfully generated');
end.{int}
```